U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN NO. 89.
L. O. HOWARD, Entomologist and Chief of Bureau.

THE GRAPE ROOT-WORM

WITH ESPECIAL REFERENCE TO INVESTIGATIONS IN THE ERIE GRAPE BELT FROM 1907 TO 1909.

BY

FRED JOHNSON AND A. G. HAMMAR,
Engaged in Deciduous Fruit Insect Investigations.
IN COOPERATION WITH THE OFFICE OF THE STATE ZOOLOGIST,
PENNSYLVANIA DEPARTMENT OF AGRICULTURE.

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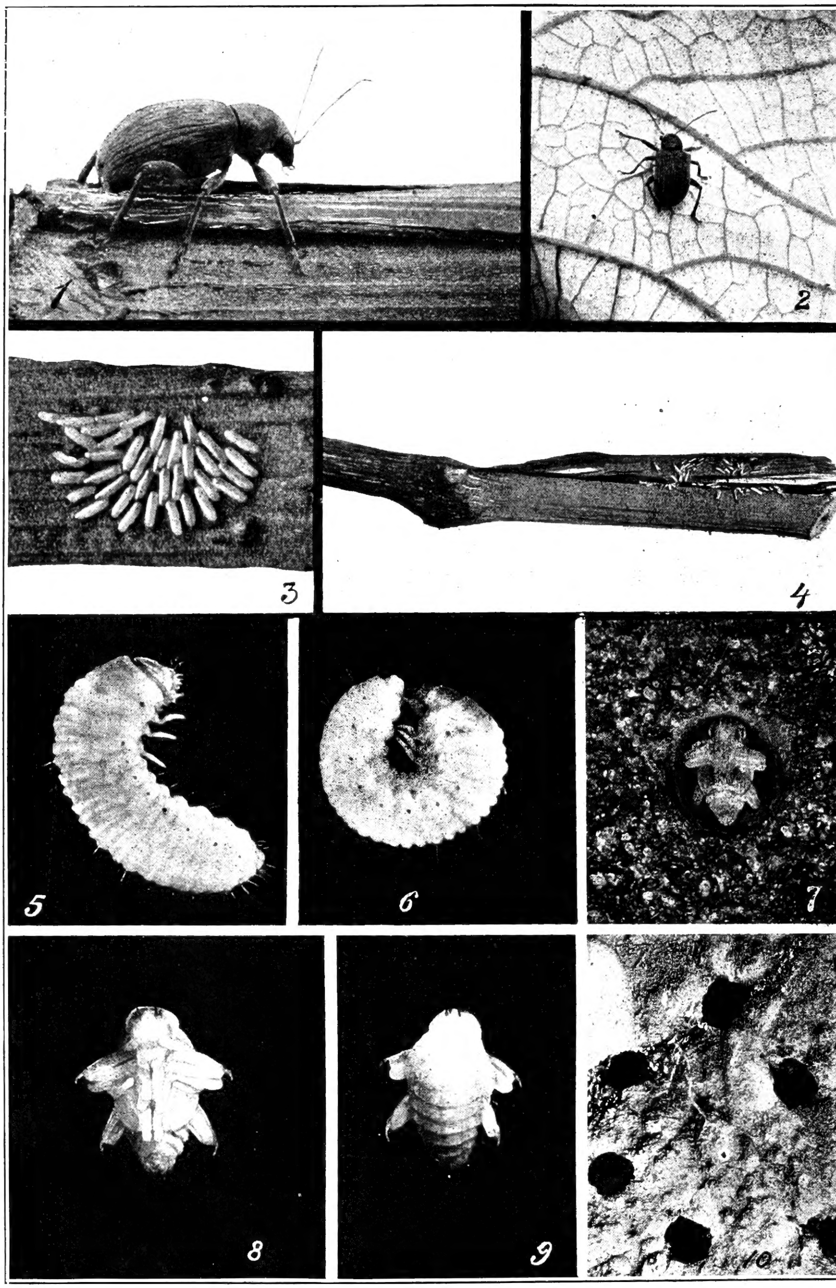

THE GRAPE ROOT-WORM (FIDIA VITICIDA).

Fig. 1.—Female beetle ovipositing. Fig. 2.—Beetle on the lower side of a grape leaf. Fig. 3.—Egg cluster with average number of eggs. Fig. 4.—Grape cane showing eggs beneath the bark. Figs. 5, 6.—Full-grown larvæ. Fig. 7.—Pupa in cell. Figs. 8, 9.—Lower and upper views of pupa. Fig. 10.—Openings in the ground from which beetles emerged. Figs. 3, 5, 6, 8, 9, enlarged; figs. 2, 10, about twice enlarged; fig. 7, about three times enlarged; fig. 1, five times enlarged; fig. 4, natural size. (Original.)

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., June 8, 1910.

Sir: I have the honor to transmit herewith for publication a manuscript entitled "The Grape Root-Worm, with Especial Reference to Investigations in the Erie Grape Belt from 1907 to 1909," by Fred Johnson and A. G. Hammar, agents and experts, of this Bureau.

The grape root-worm is by far the most serious pest of American varieties of grape at the present time and its ravages have caused a great depreciation in the value of vineyard properties as well as a marked reduction in the yield of fruit. The present report furnishes a careful account of the life history and habits of the pest, embodies a report on the work undertaken by the Bureau of Entomology in the spring of 1907 in the Erie Grape Belt, at the instance of vineyardists, and provided for by Congress, and points out practical remedial measures whereby the vineyardists will be able largely to avoid future losses.

During the years 1908 and 1909 the work has been in cooperation with the office of the zoologist of the Pennsylvania state department of agriculture, as further detailed in the preface.

I recommend the publication of the accompanying manuscript as Bulletin No. 89 of this Bureau.

Respectfully,

R. S. Clifton,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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PREFACE.

The grape root-worm, the subject of the present report, is an insect which during the last ten or fifteen years has attracted much attention on account of its ravages in vineyards along the southern and eastern shores of Lake Erie, comprising in general the grape-growing territory of northern Ohio and the Erie and Chautauqua grape belts of Pennsylvania and New York, respectively. American varieties of grapes, exclusively grown in the above-mentioned regions, have heretofore been singularly free from insects attacking the roots of the plant. The Phylloxera, so destructive to the roots of vinifera varieties in Europe and in California and elsewhere in the United States where these are grown, fortunately does not seriously injure varieties of American grapes. The grape root-worm, however, has come to be recognized as the most serious of the two hundred or more species of insects in the United States which feed directly or indirectly upon our native grapes.

The destructiveness of the insect in the Erie grape belt in the general neighborhood of North East, Pa., led, through the representations of prominent vineyardists, to a provision by Congress for an especial investigation of the pest by the Bureau of Entomology. This work was begun in the spring of 1907, and a laboratory was established at North East, Pa., which place has been continued as headquarters during the years 1908 and 1909. During the latter two years, by contract entered into between the Hon. James Wilson, Secretary of the United States Department of Agriculture, and the Hon. N. B. Critchfield, secretary of agriculture of the State of Pennsylvania, the investigation has been in cooperation with the office of the state zoologist of the Pennsylvania department of agriculture. The work has covered a wide range of investigations, including a thorough inquiry into the life history and habits of the insect, large-scale experiments with remedial measures, and the demonstration of the effectiveness of measures known to be of value, including the renovation and improvement of young and old vineyards already seriously injured.

Mr. Fred Johnson has been in immediate charge of the field work during the entire period of the investigation, and was assisted in 1907 by Messrs. W. B. Wilson and P. R. Jones, the former engaged in field work and the latter in life-history studies. During the years

1908 and 1909 Mr. A. G. Hammar was detailed to the grape root-worm investigation and devoted his attention particularly to life-history studies, assisted by Mr. E. Selkregg. Prof. H. A. Surface, state zoologist of Pennsylvania, assigned, as a representative of the Pennsylvania department of agriculture, Mr. F. Z. Hartzell during 1908, and Mr. H. B. Weiss during the year 1909. These gentlemen assisted in field operations and rendered most efficient service, contributing much to the success of the investigation. In the present report Mr. Johnson has prepared the manuscript detailing results of field experiments and Mr. Hammar the manuscript detailing results of life-history studies, and most of the illustrations.

The results obtained by this study, as detailed in the subsequent pages, will, it is believed, furnish entirely practicable and economical measures for the control by vineyardists of this serious insect pest. It is essential, however, in order that satisfactory results may be secured, that the recommendations given be followed in a thorough and timely manner.

The authors desire to express their thanks to the following vineyardists of North East, Pa.: Mr. George Blaine, Mr. W. S. Wheeler, Mr. R. Davidson, Mr. W. E. Gray, Mr. H. S. Mosher, and Mr. A. I. Loop, for their direct assistance in the conduct of this investigation by placing large blocks of their vineyards at the disposal of the Bureau of Entomology for several seasons and assisting in conducting experiments thereon. They also wish to thank the large number of vineyardists whose interest in the work during its progress has been a source of inspiration and gratification to them throughout this period.

A. L. Quaintance,
In Charge of Deciduous Fruit Insect Investigations.

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THE GRAPE ROOT-WORM

WITH ESPECIAL REFERENCE TO INVESTIGATIONS IN THE ERIE GRAPE BELT FROM 1907 TO 1909.

INTRODUCTION.

During the past decade the insect *Fidia viticida* Walsh (Pl. I), a chrysomelid beetle known to the vineyardists of the Lake Erie Valley as the "grape root-worm" beetle, which in the larval stage feeds upon the roots of the grapevine, has become by far the most destructive insect pest attacking the grape in that region.

The following pages present the extent and findings of an investigation conducted at North East, Pa., during the seasons of 1907, 1908, and 1909. These investigations were undertaken in order to make a thorough study of the life history and habits of this insect, to conduct experiments with a view to its control, and to make field experiments to demonstrate the practical commercial value of those methods giving greatest promise of effective results.

Since the grape root-worm is a grape pest of long standing, a brief résumé of its history is given, both from the standpoint of entomological classification and from that of the development of remedial measures for its control.

Its origin, distribution, and food plants are considered, brief descriptions of allied beetles and of those beetles found upon grapevines likely to be mistaken for the grape root-worm are given, and also a description of the character of the injury to the vine wrought by the insect and the extent of its destructiveness.

The technical descriptions of the different ages of the insect are followed by a presentation of life-history studies involving many careful experiments with numerous individuals. These studies were undertaken to determine the length of the stages and the time at which the different changes occur. This work was conducted for three consecutive years with a view to determine the effect, in the development of the insect, of seasonal variations due to varying climatic conditions, and it has been productive of very interesting results which have an important bearing on the time of application of remedies. Soil conditions and altitude of vineyards are also considered in this same relation.

Preceding the discussion of remedial measures a brief summary is given of the conditions in vineyards in the Lake Erie Valley since their invasion by the grape root-worm, dealing with the age and condition of vines at the time of its advent, the increase in area of new vineyards, the insect's comparative destructiveness to old and newly planted vines, and the relative responsibility of the pest for the fluctuations of crop yields during the past decade.

Cultural methods are considered with special reference to the destruction of pupæ in the soil.

In the presentation of the data dealing with poison sprays for the destruction of the beetles, details of experiments are given, first, to show the efficiency of arsenicals as a direct killing agent of the beetles in confinement and also in the open field; second, to show the relative value of arsenate of lead and of arsenite of lime; and, third, to show the cumulative value of poison-spray applications on large vineyard areas, both in crop yield and in vigor of vines as a result of three consecutive years of this treatment.

Following this experimental data on poison sprays the details are given of field demonstration experiments with two run-down vineyards, conducted for three consecutive seasons. One, an old vineyard of about 10 acres, the other a young vineyard of about 5 acres. The condition of each of these vineyards at the time the experiment was undertaken is described and the plan of treatment—covering general vineyard practice, such as pruning back of badly injured vines, fertilizing, cultivation, and spraying with arsenicals—is given, accompanied by the collected data showing the results of this treatment in lessening deposition of eggs by the grape root-worm beetles, in the diminution of grape root-worm larvæ in the soil about the roots of the vine, in the increase in crop yield, and in the general effect of this combined treatment upon the health and vigor of the vines.

The remaining pages contain a brief discussion of arsenicals as stomach poisons against the grape root-worm beetles, the desirability of combining them with a fungicide when spraying for this pest, spraying methods and spraying machinery as related to vineyard treatment, and recommendations as to time and manner of making applications.

HISTORY.

The first record of the beetle, *Fidia viticida,* the adult of the grape root-worm, as a pest of economic importance upon grapevines was made by B. D. Walsh in 1866 in the Practical Entomologist (see Bibliography), and it is also to him that we are indebted for the first description of this species of the genus Fidia. Yet as far back as 1826 this insect appears in entomological literature under a variety

of names. The first reference we find to this species is in M. J. Sturm's Catalog Insecten Sammlung, at that date (1826) under the name of *Colaspis flavescens*. Under a later catalogue (1843) by the same author it is listed under the name of *Fidia lurida* Dej. Dejean, in his Catalogue des Coléoptères (1837), names two species, *Fidia lurida* Dej. and *Fidia murina* Dej.

The genus Fidia was first characterized by Baly in 1863, who used the name Fidia suggested earlier by Dejean. Crotch, however, in 1873, described this insect under the name of *F. murina* and Lefevre, in 1885, described it under *F. lurida*. In 1892, when Dr. George H. Horn revised the Eumolpini of Boreal America, *F. murina* and *F. lurida* were found to be synonyms of *Fidia viticida* as described by Walsh in 1867.[a]

Since 1866, when this insect was first reported as occurring in destructive numbers in Kentucky, it has developed into the most serious insect infesting vineyards east of the Rocky Mountains. At that date only the adult form and its injury to the vine by feeding upon the foliage was known. Walsh assumed that the larval habits of the pest were similar to those of the grape flea-beetle (*Haltica chalybea* Ill.), and that it would be found the most destructive in this stage feeding upon the foliage. In the former assumption he was correct, for it is the injury of the larval form which is inimical to infested vines, not upon the leaves, however, as Walsh supposed, but upon the roots, as shown by later investigations. The year following, the insect was reported from St. Louis and Bluffton, Mo., and in 1868 Prof. C. V. Riley, in his first report on injurious and beneficial insects of Missouri, mentions it as "the worst foe to the grapevine in Missouri." In 1870 specimens were received by Riley from Bunker Hill, Ill., and in 1872 Mr. S. H. Kridelbaugh reported it present in Iowa in injurious numbers.

It was not until 1893, however, that some light was thrown upon the earlier stages of the pest. In December of that year Prof. F. M. Webster, then entomologist of the Ohio Agricultural Experiment Station, received larvæ from the vicinity of Cleveland, Ohio, where they were said to occur in great numbers about the roots of vines. Later there developed from these larvæ the complete form which proved to be the beetle *Fidia viticida*, hitherto the only stage of the

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[a] The validity of the technical name of the grape root-worm (*Fidia viticida* Walsh) might be questioned. The names *lurida* and *murina* were used previous to *viticida*, but as *nomina nuda;* the specific description was first given in 1867, when Walsh described the insect under the name *Fidia viticida*. Baly in 1863 characterized the genus and designated *lurida* as the type of the genus, though the species under that name had not yet been described. The specific name *viticida* Walsh has the priority, since the valid name *murina* was first used in 1873 by Crotch, and *lurida* in 1885 by Lefevre, both writers using the early manuscript name of Dejean.

insect known to entomologists. During the season of 1894 Professor Webster made a detailed and accurate study of the life history of the insect, described its immature stages, and made numerous field experiments to determine effective methods of control, which are referred to in another part of this bulletin.

In 1896 Prof. J. T. Stimson recorded injury caused by this insect in Arkansas. Dr. John B. Smith, in his Catalogue of Insects of New Jersey, 1900, reports its occurrence throughout that State. Dr. L. O. Howard reported it from Bloomington, Ill., in 1901. In later years the insect appeared as a pest in the grape region of Pennsylvania and New York, where from 1900 to 1906 it was the subject of detailed studies, treating both of its life history and remedial measures, by the late Prof. M. V. Slingerland, of Cornell University,

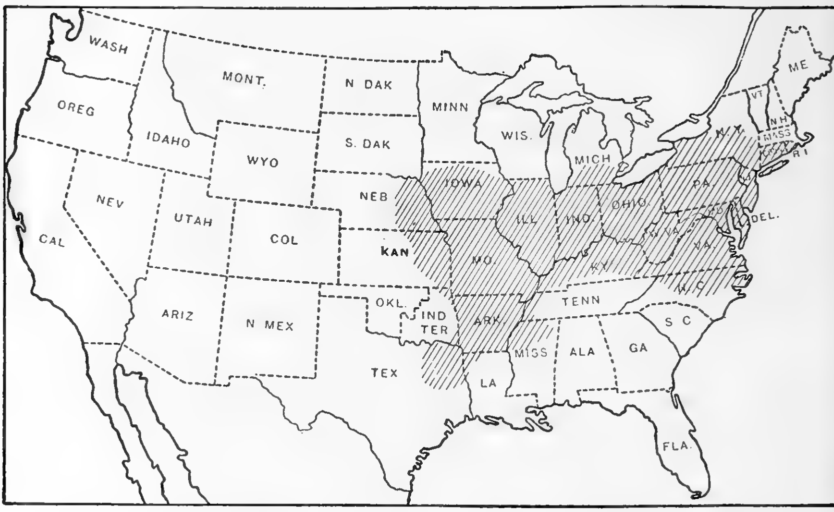


FIG. 1.—Map showing distribution of the grape root-worm (*Fidia viticida*). (Original.)

and by Dr. E. P. Felt, state entomologist of New York. The reports of the investigations by the former are embodied in the bulletins of the entomological division of Cornell University, and the publications of the New York State Museum contain reports of those made by the latter; all publications of these two investigations are listed in the bibliography accompanying this bulletin.

ORIGIN AND DISTRIBUTION.

The grape root-worm has at present been recorded only from North America, and it is without doubt a native species, feeding originally on wild grapevines, as it still does to some extent.

The insect is widely distributed in the Mississippi Valley and in the Eastern States. The map (fig. 1) shows the distribution as recorded at present.

In literature the insect is reported from the following States: Arkansas (Riley, Howard, and Stimson); Illinois (Walsh and Riley); Iowa (Kridelbaugh); Kansas (Webster); Kentucky (Walsh); Missouri (Riley); New Jersey (Smith); New York (Lintner, Slingerland, and Felt); Ohio (Webster); Pennsylvania (Slingerland and Felt).

According to records of the Bureau of Entomology the insect occurs in Illinois, Kentucky, Michigan, Mississippi, Missouri, New York, North Carolina, Ohio, Pennsylvania, Texas, Virginia, and West Virginia.

In the collections of the National Museum are specimens from the following States: District of Columbia, Illinois, Kansas, Maryland, Missouri, Nebraska, New York, North Carolina, Ohio, Pennsylvania, Texas, and Virginia.

From the following localities it has not yet been recorded, but probably does occur as these are neighboring sections of infested places: Southern parts of Indian Territory, Tennessee, and Wisconsin; northern parts of Alabama, Georgia, Louisiana, and South Carolina.

FOOD PLANTS.

From early records of this insect it is evident that the beetle of the grape root-worm was observed feeding upon wild grapes long before it was known to infest cultivated varieties. Riley reported the beetle feeding upon the leaves of wild grapes and upon the redbud (*Cercis canadensis*). Several writers have found it feeding upon the foliage of the Virginia creeper (*Ampelopsis quinquefolia*). With the extensive cultivation of improved varieties of native species of grapes, the insect has found in these a more available food plant. The larval form and its underground habits became first known through its abundance and destructiveness in vineyards.

On the wild grapevine the grape root-worm does not breed in extensive numbers, because the conditions in woodlands are less favorable than those existing in vineyards. The chances for the newly hatched larvæ to reach the roots of the wild grapevine are greatly limited, since the plants spread their aerial growth extensively and in such a manner that the parts of the vine above ground are not directly above the root system. Under such conditions numbers of the larvæ on dropping to the ground do not reach the needed food plant and probably perish. A single female beetle, however, lays a considerable number of eggs, and out of the many hatching larvæ the chances are that always several will survive to perpetuate the species.

In the course of this investigation at North East, Pa., several attempts were made to locate the larvæ on roots of wild grapevines, but in no instance were larvæ found or any signs of feeding observed on

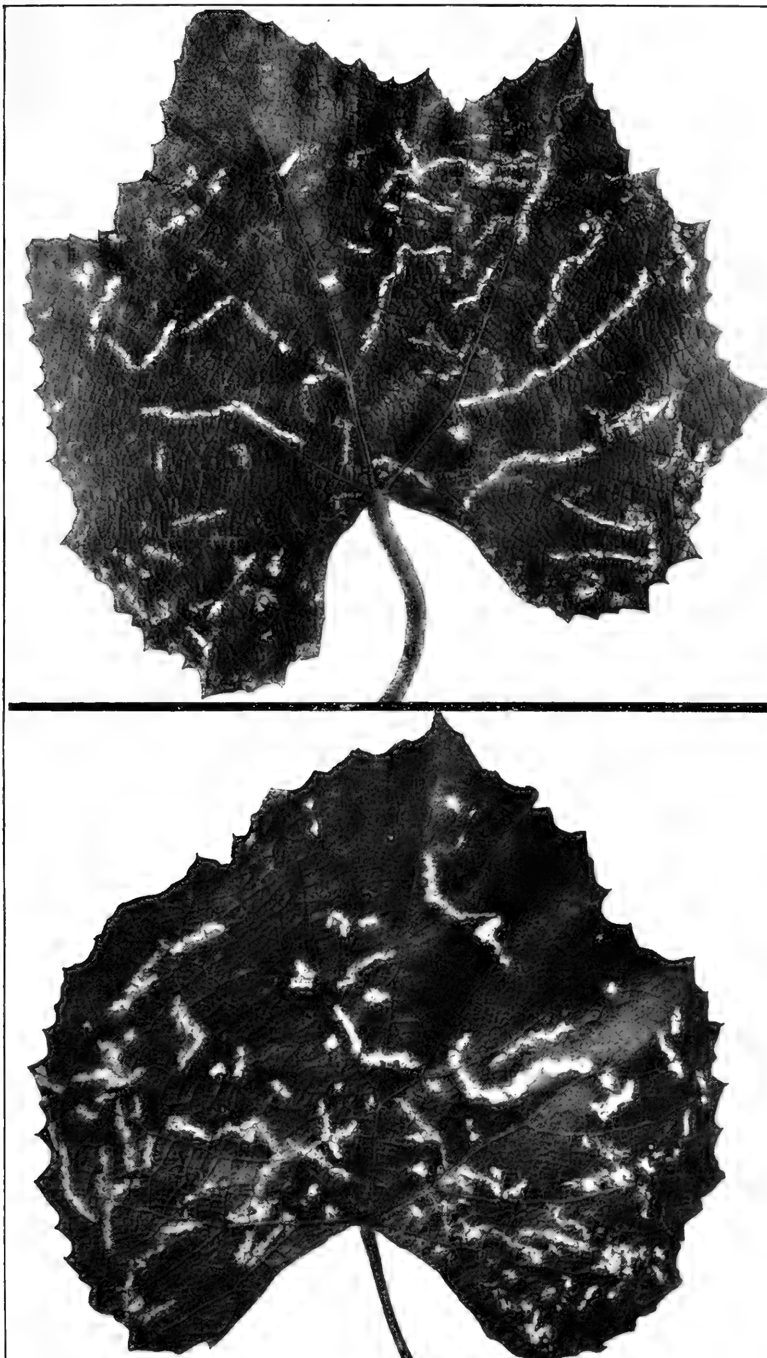
the roots. In the breeding work, however, larvæ were reared on wild grapevines, which shows that it is possible for the larvæ to exist on these plants. In 1909 larvæ hatching July 26 were placed in large earthen pots (fig. 22) in which, some time previously, wild grapevines had been planted. On examining the cages in the fall of the same year (1909) a number of larvæ were found to have attained their normal growth, as compared with other larvæ reared under similar conditions on cultivated vines.

CHARACTER OF INJURY AND DESTRUCTIVENESS.

The injury wrought by this pest on the grapevine occurs both above and below the surface of the ground; however, by far the greater damage results from its work upon the roots. The injury above the ground is done by the beetles; that upon the roots by the grubs or larvæ.

The first intimation that the observant vineyardist is likely to obtain of the presence of this pest upon his vines is the appearance, late in June or early in July, of chainlike markings upon the upper surface of the foliage (Pl. II). These markings are made by the beetle. Ordinarily this scoring of the leaves is not sufficient to materially affect the health of full-grown thrifty vines. Where the beetles are very numerous, however, and the foliage sparse, it not infrequently happens that the leaves are so badly scored that in a short time they take on a brown appearance and hang about in shreds. In the case of newly planted vines (fig. 29) extensive feeding by the beetles greatly retards the growth of the young plant and proves a great obstacle in the starting of a new vineyard. On the thick-leaved varieties of grapes, such as the Concord, Worden, and Niagara, this feeding does not extend through the heavy pubescence on the lower surface. The pubescence holds together only a short time, however, and soon either dries out or is torn apart by the growth of the leaf. On the thin-leaved varieties, as the Delaware, and on the wild species of grape, holes are eaten entirely through the leaf, usually assuming the characteristic chainlike irregularity of form.

It is, however, to the larvæ of this pest feeding upon the roots of the vines that the direct cause of the injury and death of so many vines is due. The work of the larvæ upon the roots may be recognized, when the vines are removed from the soil, by the absence of root fibers, by channels along the larger roots, and by pittings on the main trunk. (See Pl. III.) Vines that have become well established before the infestation by larvæ will sometimes withstand the attack of a considerable number of grubs, especially if the soil is rich and has been well tilled. The evidence of continued heavy infestation is indicated by absence of fibers upon the whiplike roots



FEEDING MARKS ON GRAPE LEAVES, MADE BY THE BEETLE OF THE GRAPE ROOT-WORM.

Fig. 1.—Appearance of fresh feeding marks. Fig. 2.—Feeding marks which have become enlarged with the growth of the leaf. Natural size. (Original.)

FEEDING MARKS ON THE LARGER ROOTS AND UNDERGROUND PART OF THE STEM OF A GRAPEVINE BY LARVÆ OF THE GRAPE ROOT-WORM, RESULTING IN THE DEATH OF THE PLANT. LOWER FIGURE NATURAL SIZE. (ORIGINAL.)

(Pl. IV, fig. 2, in comparison with fig. 1) extending from the main root a distance of several feet. The extremities of such roots are frequently dead and in a decaying condition, and the portion near the stem is much channeled and pitted by the feeding of the larger larvæ (Pl. III). The life of such vines during this infestation has been sustained by the throwing out of new fibrous roots either at the crown or from the large lateral roots at a short distance from the base of the vine. If the number of larvæ increases sufficiently to eat off these new fibers, the whole vine declines quite rapidly, and the effect of the attack is readily recognized by a sickly stunted growth of vine and undersized clusters of fruit, and in extreme cases by the early shedding of foliage and actual shriveling of fruit before the ripening period.

BEETLES RELATED TO THE GRAPE ROOT-WORM BEETLE.

The grape root-worm is a member of the large group of leaf-eating beetles known as the Chrysomelidæ. To this family belong the common Colorado potato beetle (*Leptinotarsa decemlineata* Say), the elm leaf-beetle (*Galerucella luteola* Müll.), the asparagus beetle (*Crioceris asparagi* L.), several important pests of the genus Diabrotica, the grapevine flea-beetle (*Haltica chalybea* Ill.), and many other injurious beetles.

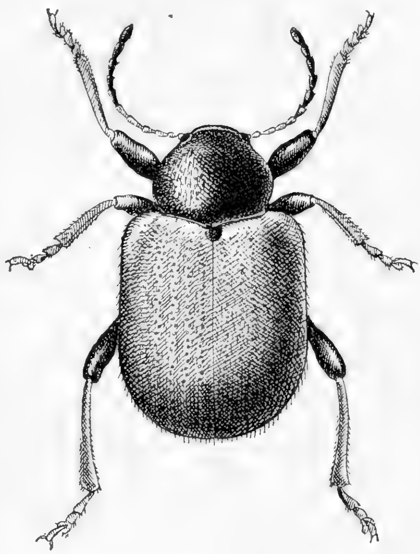


FIG. 2.—The California grape root-worm (*Adoxus obscurus*): Adult or beetle. Much enlarged. (Original.)

Closely related to *Fidia viticida* Walsh (fig. 10) is the California grape root-worm (*Adoxus obscurus* L.) (fig. 2), of which there are two varieties, namely, a black form, known as *A. obscurus*, and a bicolored form, known as *A. obscurus vitis*. Both varieties occur in this country and have been reported from several widely separated States and from Canada. It is found generally in Europe and throughout Siberia. At present it is becoming injurious to vineyards in California, infesting the European varieties of the cultivated grape. A valuable contribution to the knowledge of this insect was published by Mr. H. J. Quayle [a] in 1908. In habits this beetle is in most respects similar to the eastern grape root-worm, *Fidia viticida*, and the two pests can thus be combated with similar methods. It will, however, be necessary to take into consideration the local conditions

[a] Bul. 195, Cal. Agr. Exp. Sta., 1908.

and variations as to the habits of the beetles in order to accomplish effective results.

There are at present 6 species of the genus Fidia known to Boreal America and by including those occurring in Central America there are 14 known species. Of these, *Fidia viticida* Walsh and *Fidia longipes* Melsh. have been recorded as being injurious to the native varieties of the domesticated grape. *Fidia longipes* (fig. 3) is found generally throughout the Mississippi Valley and in the Eastern States. It is, however, less common than *F. viticida.* In Missouri and Kentucky it occurred in injurious numbers on the Concord and on Norton's Virginia varieties of grapes. The earlier stages of this beetle are not yet known.

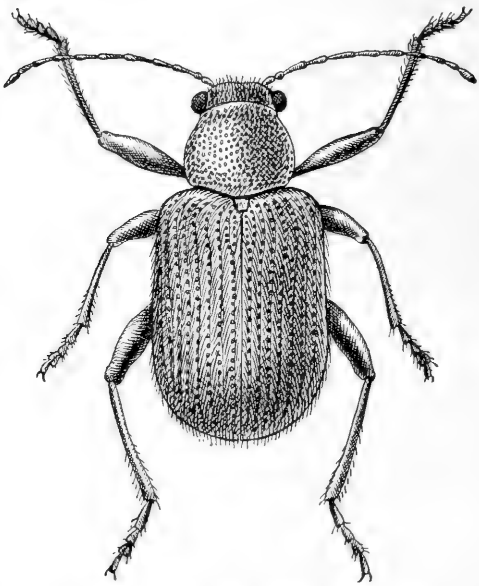


Fig. 3.—The grapevine Fidia (*Fidia longipes*): Adult or beetle. Much enlarged. (Original.)

For characteristic distinction of the species of Fidia reference is made to the works of Lefevre, Jacoby, Horn, and Schæffer, as listed in the appended bibliography (p. 93).

BEETLES FREQUENTLY MISTAKEN FOR THE GRAPE ROOT-WORM BEETLE.

There are several different kinds of beetles injurious to the grapevine, and these when found in numbers are frequently mistaken for the grape root-worm beetles. It is essential that an insect pest should be properly determined before any successful control measure can be properly recommended. Although most leaf-eating beetles can be controlled with a poison spray, as used against the grape root-worm, there exists a marked difference in the time of appearance of

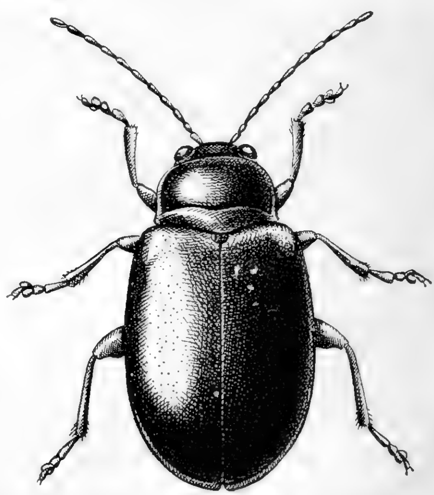


Fig. 4.—The grapevine flea-beetle (*Haltica chalybea*): Adult. Much enlarged. (Original.)

Fig. 1.—Five-year-old grapevine with normally developed root-system; enlarged portion showing root fibers. (Original.)

Fig. 2.—Four-year-old grapevine, showing result of feeding by larvæ of the grape root-worm. (Original.)

DESTRUCTION OF ROOT FIBERS BY LARVÆ.

the different pests, so that an application intended for one may not at all affect another. The descriptions with figures of the following beetles and of their more characteristic habits will aid the vineyardist in distinguishing the grape root-worm from other injurious species.

The grapevine flea-beetle (*Haltica chalybea* Ill.) (fig. 4), measuring about one-fifth of an inch in length, is readily recognized by its brilliant metallic color, which varies from steel blue to green. It is of a robust shape, with thickened thighs well adapted for jumping. With the opening of the buds of the grapevine in the spring the beetle generally makes its appearance. The larvæ, which are found in the early part of the summer, feed, like the adult, upon the leaves of the grape.

The rose-chafer (*Macrodactylus subspinosus* Fab.) (fig. 5) appears as a rule at the time of the blossom of the grape. It is a slender beetle about one-third of an inch long, with the body tapering a little toward each extremity. It is covered with a grayish-yellow down, which gives rise to its color. The pale reddish legs are long, at the joint armed with prominent spines, and terminate in very long black claws. The antennæ, or "feelers," are short and have at the end a laminated club-like structure. The beetle readily attracts attention because of its activity and great abundance wherever present. It preferably feeds upon the clusters of the blossom, and to some extent upon young grape-berries and leaves.

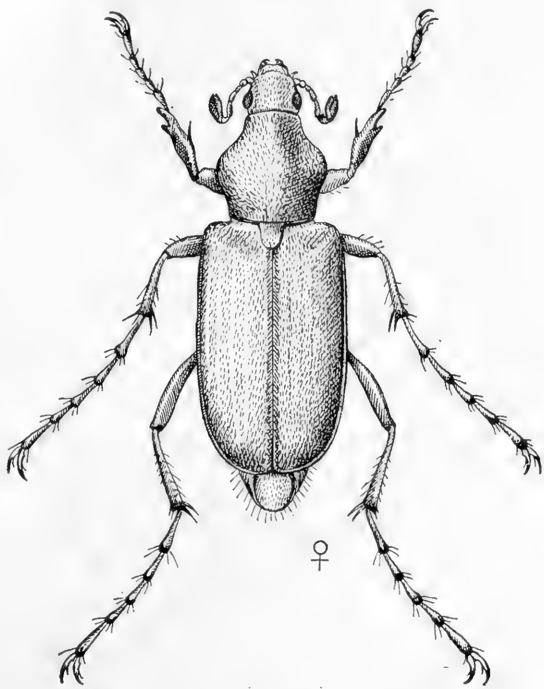


FIG. 5.—The rose-chafer (*Macrodactylus subspinosus*): Adult or beetle. Much enlarged. (Original.)

The red-headed Systena (*Systena frontalis* Fab.) (fig. 6) somewhat resembles the previously described beetle. It is, however, smaller, measuring about one-sixth of an inch in length, and is black in color except for a pale reddish area between the eyes. This beetle has of late become quite injurious to young grapevines, feeding upon the leaves to such an extent that it often kills the vines. The feeding

marks of the beetles are quite characteristic, consisting of round patches eaten into the parenchyma from the upper surface of the leaves. It is a very shy little creature, and on the slightest disturbance jumps off and hides beneath the foliage. Young vineyards when infested should be promptly sprayed with a mixture of from 5 to 8 pounds of arsenate of lead to 100 gallons of water. This gives the plants a very good protection. The earlier stages of this insect are not known.

The grapevine Colaspis (*Colaspis brunnea* Fab.) (fig. 7) in its general appearance resembles the grape root-worm beetle. It is, however, slightly smaller, has no pubescence, and is of a pale yellowish color. It is nearly one-fifth of an inch long, with the body densely punctate. On the

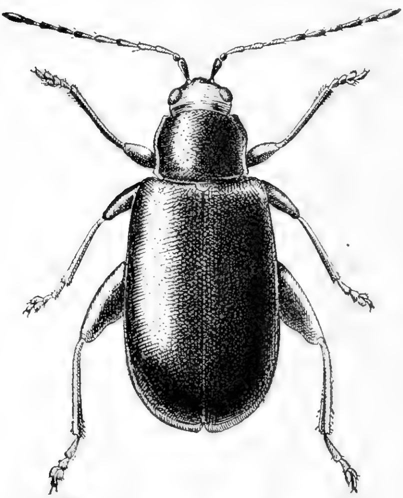


FIG. 6.—The redheaded Systena (*Systena frontalis*): Adult or beetle. Much enlarged. (Original.)

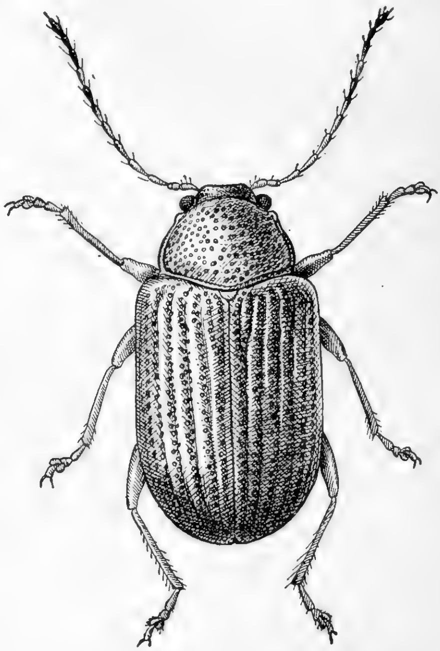


FIG. 7.—The grapevine Colaspis (*Colaspis brunnea*): Adult or beetle. Much enlarged. (Original.)

wing covers the deep punctures are arranged in double longitudinal rows or striæ. The beetle feeds upon the grape foliage in a manner more or less similar to that of the grape root-worm beetle.

It is not within the scope of this paper to treat the various insect problems, such as those of the grape leafhopper (*Typhlocyba comes* Say), the grapeberry moth (*Polychrosis viteana* Clem.), the grape curculio (*Craponius inæqualis* Say), and others, which from time to time confront the vineyardist. These pests demand special treatment, and in cases of serious infestation an entomologist should be consulted. It has, however, been our observation that well cultivated

and properly sprayed vineyards are less subject to the attacks of insects. Such infestations are very frequently the direct outcome of neglect in the general care of vineyards, as is more fully considered elsewhere in this bulletin.

DESCRIPTION.

THE EGG.

(Pl. I, figs. 3–4.)

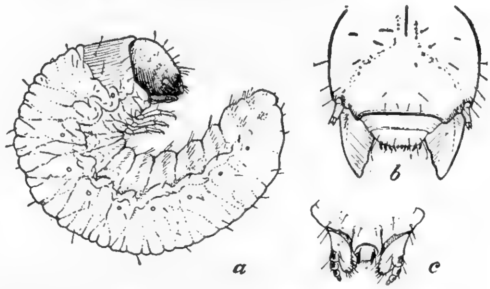


Fig. 8.—The grape root-worm (*Fidia viticida*). Larva: *a*, Side view of full-grown larva; *b*, front view of head; *c*, maxillæ and labium. Much enlarged. (Original.)

The eggs of the grape root-worm beetle are small yellowish-white objects, measuring 1.15 mm. in length and are about one-third as broad as long. In form the egg is cylindrical, with the two ends almost hemispherical. As the shell is very flexible and the eggs are generally laid crosswise on the canes, they often assume a slightly curved shape. Through the semitransparent shell the segmentation of the embryo can be seen, and later, as the young larva attains its full development, the head with the dark-colored mandibles becomes clearly visible. Prof. F. M. Webster observed the larva backing out from the eggshell in the process of hatching.

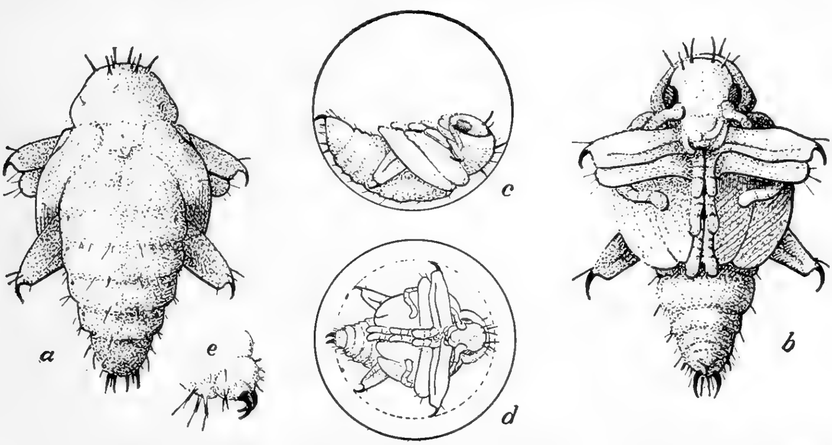


Fig. 9.—The grape root-worm. Pupa: *a*, Upper view; *b*, lower view; *c*, normal position of pupa in cell; *c*, *d*, showing the pupa supported by the spines in the cell; *e*, hind part of body, showing terminal spines. Much enlarged. (Original.)

THE LARVA.

(Pl. I, figs. 5–6; text fig. 8.)

The full-grown larva varies in length from 8 to 10 mm. It is whitish, with the head, thoracic shield, and spiracles pale brown.

The mandibles and the margin of the clypeus and areas around the antennæ are almost black. The anterior margin of the upper lip is armed with short and stout spines (fig. 8, *b*), and as the inner surface is reenforced by chitinous ridges extending inward, its function is probably that of a scraper. The setæ on the head and on the cervical shield are rather prominent; those on the sides and back of the body are less conspicuous. The ventral parts of the abdominal segments are armed with strong spines, which are particularly large on the fourth to the eighth segments. These project obliquely backward and are properly termed ambulatory setæ. The legs are slender and proportionately very small. Normally the larva assumes a curved position (fig. 8, *a*). The anterior portion of the body can be straightened out at will, but the hinder parts remain curved, which is characteristic of the larvæ of most underground beetles. The newly hatched larva is little over 1 mm. in length and of slender form; the legs are relatively large, and the setæ of the entire body are long and prominent.

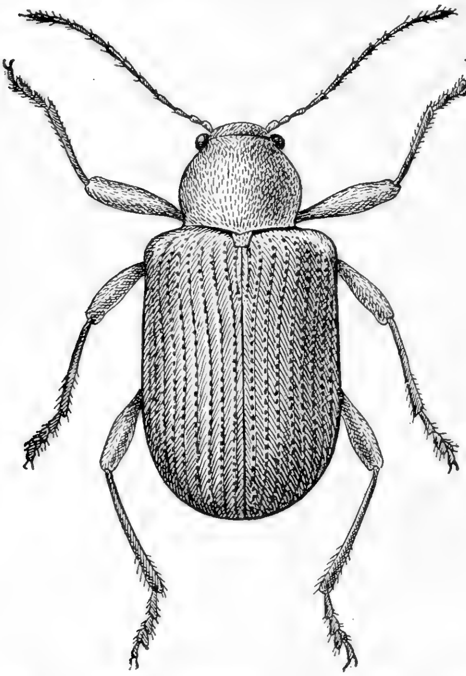


FIG. 10.—The grape root-worm: Adult or beetle. Much enlarged. (Original.)

THE PUPA.

(Pl. I, figs. 7–9; text fig. 9.)

The length of the pupa is from 8 to 10 mm. When newly transformed it is whitish, with a slightly pinkish tinge, which in a few days after pupation disappears and the pupa becomes white. The upper part of the head and anterior margin of the thorax are armed with large spines; each anterior and posterior femur is armed with one curved hooklike spine and two straight, more slender spines. The middle femora have only hairlike bristles. The posterior end of the abdomen carries two stout, flattened hooks, curved upward, and several pairs of spines and bristles (fig. 9, *c* and *d*). The pupa in the

cell is supported by these larger spines and its body is not in touch with the moist walls of the cell. As these large and strongly chitinized spines do not occur in either the larval or the adult form of the insects, it is probable that their main function is to support the pupa in the cell.

THE ADULT OR BEETLE.

(Pl. I, figs. 1-2; text figs. 10, 11.)

The original description of the beetle as made by Walsh is given below:

Fidia viticida, new species. Chestnut rufous, punctured and densely covered with short grayish white prostrate hairs, so as to appear hoary. *Head* rather closely punctured, with a very fine longitudinal stria on the vertex. Clypeus and mandibles glabrous and black, the clypeus with a subterminal transverse row of punctures, armed with long golden hairs, the mandibles minutely punctured on their basal half. Palpi and antennæ honey-yellow verging on rufous, the antennæ ¾ as long as the body, with joint 4 fully ½ longer than joint 3. *Thorax* finely and confluently punctured, about as long as wide, rather wider behind than before, the sides in a convex circular arc of not quite 60°, the males with the thorax rather longer and laterally less strongly curved than the females. Elytra punctato-striate, the striæ subobsolete, the punctures approximate, and rather large but not deep, the interstices flat and with close-set fine shallow punctures. *Legs* with the anterior tibiæ of the male suddenly crooked ¾ of the way to their tip; anterior tibiæ of the female as straight as the others. Length ♂ .24-.27 inch; ♀ .24-.28 inch.

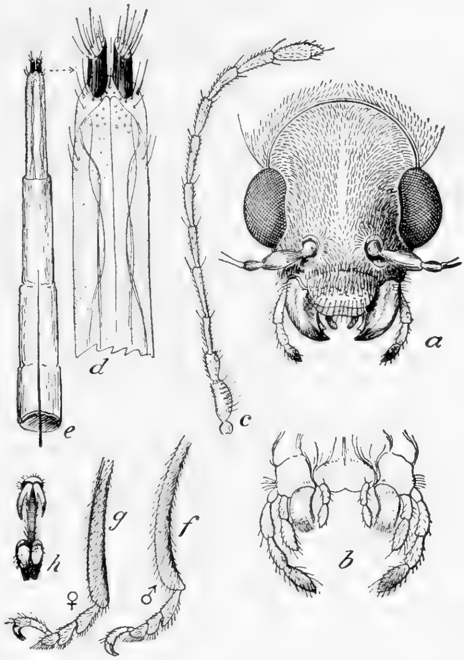


FIG. 11.—The grape root-worm: Structural parts of the adult or beetle—*a*, Front view of head, showing biting mouth parts; *b*, lower view of labium and maxillæ; *c*, antenna or "feeler;" *d*, terminal portion of the ovipositor; *e*, ovipositor with membranous portion extended; *f*, front leg of male beetle; *g*, front leg of female beetle; *h*, claws of tarsus. All parts greatly enlarged. (Original.)

The ovipositor of the female (fig. 11, *d, e*) consists of a more or less solid terminal portion and a membranous proximal part. Ordinarily it remains completely withdrawn within the abdominal cavity, where the terminal part lies within the membrane, which is folded into three parts. Meso-ventrally the membrane is supported by a slender chitinous rod (fig. 11, *e*). In the terminal portion are a pair of chitinous rods. Fully extended, the ovipositor is three times the length of the abdomen.

SEASONAL HISTORY.

The grape root-worm attains its growth during the feeding period of the larvæ. The pupal stage, following the long larval period, is a process of transformation, whereby all the internal organs, and to some extent the external parts, become reconstructed, resulting, with the throwing off of the pupal skin, in the appearance of the beetle. It is during this latter stage and in the early part of the summer that reproduction occurs.

The diagram (fig. 12) will, it is believed, greatly aid the reader in comprehending the development and the activity of the grape root-worm in its various stages throughout its life cycle. This illustration has been compiled from both field and rearing observations and represents the life of a single beetle under average conditions.

In the following consideration of the life history of the grape root-worm is presented the results of rearing experiments and field observations for the year 1909. In most respects that year was normal as regards climatic conditions and the insect developed as might be expected under average conditions. In view of the extreme variations in the development of the insect during 1907 and 1908, the records of observations for these years have been treated under the topic "Seasonal variations in the life history of the grape root-worm." The rearing and experimental methods relating to the tables of the life-history work are described separately on pages 44–50.

THE ADULT OR BEETLE.

THE PROCESS AND TIME OF EMERGENCE.

Prior to its emergence the beetle spends several days in the pupal cell and at the time of the shedding of the pupal skin is of a light turbid yellowish cast, and is comparatively soft and for a time helpless. On an average the beetles remain 4 days in the cell, while the parts of the body harden. In Table XV (p. 38) are given 25 observations on the length of time the beetles remain in the cell after transformation. In one instance a beetle remained in the cell 7 days. The minimum length of time was 2 days. Dead beetles have been found in cells, both in the breeding cages and in the ground in vineyards. This occurrence, however, has not been found sufficiently common to cause any material reduction in the number of insects.

The time required by the beetle in passing through the soil to the surface varies considerably with the distance to be covered and the texture and moisture of the soil. It has been possible to make only a few observations on the process of emerging. These were made in breeding cages with glass sides, in which the beetles have worked their way out to the edge of the soil next to the glass. One beetle which left the cell July 6 emerged July 9. On its way upward it had

to dig around a flat pebble, and as a result passed through $3\frac{1}{2}$ inches of soil. Another beetle left the cell July 5 and emerged July 6, having penetrated the soil for a distance of 1 inch. A third beetle left the cell July 16 and emerged July 19, in which time it worked through 2 inches of soil. In the process of digging, the beetles make use of the mandibles and to some extent also of the legs. The cells become partly filled with earth by material being pushed behind and beneath the beetle. In this process the channel is refilled and only a small hole is left on the surface to indicate where the beetle emerged (Pl.

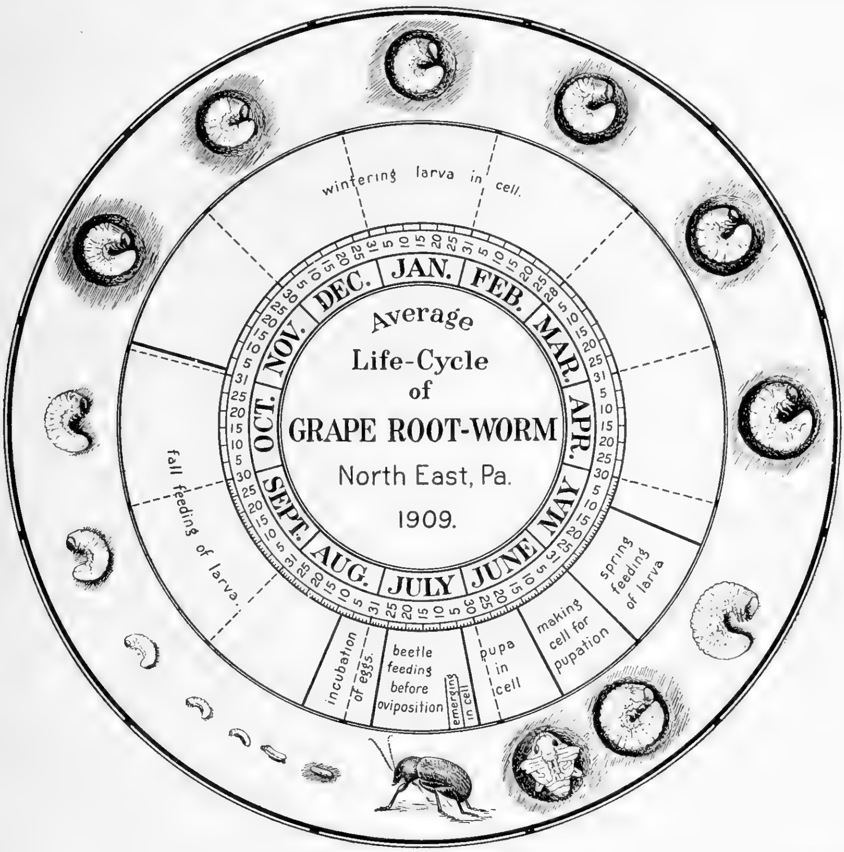


FIG. 12.—Diagram showing time and development of a single individual of the grape root-worm under average conditions, as observed in 1909, at North East, Pa. (Original.)

I, fig. 10). In vineyards where the ground remains undisturbed such openings can be readily found during the emergence period of the beetle.

In 1909 the first beetles observed in the field were collected by the senior author June 28, and, since daily observations were made of vineyard conditions, this record probably represents the earliest occurrence of the beetle for the season. In the breeding cages the

first beetle emerged July 1, which shows a fairly uniform emergence of beetles in captivity as compared with their emergence in the field. The results of the emergence experiments are given in Table I.

TABLE I.—*Date of the emergence of 398 grape root-worm beetles (Fidia viticida) from the ground, as observed in the breeding cages in the spring and early part of the summer of 1909 at North East, Pa.*

Date.	Number of beetles.	Date.	Number of beetles.	Date.	Number of beetles.	Date.	Number of beetles.
July 1.....	5	July 9.....	36	July 17....	8	July 27....	4
July 2.....	9	July 10....	39	July 18....	4	July 29....	1
July 3.....	16	July 11....	19	July 19....	5	July 30....	2
July 4.....	11	July 12....	36	July 20....	2	Aug. 5....	1
July 5.....	15	July 13....	22	July 22....	6	Aug. 9....	1
July 6.....	27	July 14....	16	July 23....	1	....	....
July 7.....	34	July 15....	26	July 24....	5	....	....
July 8.....	31	July 16....	14	July 25....	2	....	....
Total..	148	Total..	208	Total..	33	Total..	9

In figure 13 the curve shows more graphically the relative emergence of these beetles. It will be noted from this curve that after

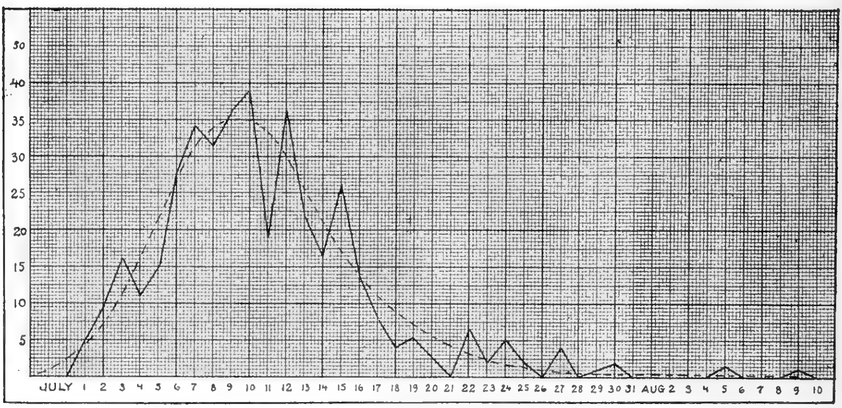


FIG. 13.—Curve showing time and relative emergence of beetles of the grape root-worm from the ground in rearing cages at North East, Pa., 1909. (Original.)

the first emergence the beetles continued to appear in rapidly increasing numbers, reaching a maximum July 10. The decrease in the number of beetles emerging after this date was more gradual, and emergence continued until late in the season. In the cages the last beetle emerged August 9, while in the field a single beetle was still found in the cell August 14. From July 1 to July 5, inclusive, 14.1 per cent had emerged; from July 6 to July 16, 75.4 per cent had emerged; and the remaining 10.5 per cent emerged later. Thus the great majority of over 75 per cent emerged during a period of 10 days, and the maximum of emergence took place about 2 weeks after the first beetle had been observed in the field.

VARIATION IN THE TIME OF EMERGENCE.

The variation found in the time of emergence of beetles in different vineyards and even in different sections of the same vineyard is due to various factors, such as temperature, moisture, porosity and texture of the soil, etc.

Since larvæ are found more abundantly in the looser porous soils than in the heavy, compact clay soils, and since the former soils are warmer, it is but natural that the insect should emerge earlier under these conditions. This fact is confirmed by observations presented in figure 14, which shows the relative emergence of beetles from three grades of soil. For these experiments a number of larvæ were collected in the early spring from different localities in the vicinity of North East, Pa. They were confined in large earthen pots (fig. 22) with the same kinds of soil in which they had been collected. Since these larvæ were supplied with a sufficient amount of food and the

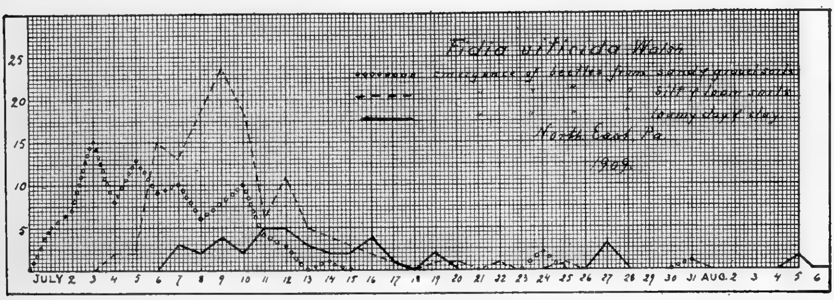


FIG. 14.—Curves showing variations in time of emergence of beetles of the grape root-worm from different kinds of soil. From rearing experiments during 1909 at North East, Pa. (Original.)

pots were placed in the ground in the open, it is believed that their normal conditions had been changed but slightly. The emergence of beetles from the sandy and gravelly soil was seven days earlier than the emergence from the clay soil.

In the vicinity of North East, Pa., the authors have observed that the emergence of the beetle in vineyards situated on the hills is one week later than the emergence in vineyards in the valley. This delay is not merely confined to the time of emergence of the beetles, but has been observed in practically all the different stages of the insect, as can be verified from the various tables of field observations.

FEEDING BEFORE AND AFTER EGG DEPOSITION.

At the time of emergence from the ground the beetle seems to possess a keen appetite. It readily finds its way to the grape foliage, and generally feeds upon the first leaf that it encounters. The leaves of the lower shoots are frequently found badly mutilated as a result

of this first feeding. The voracity with which newly emerged beetles feed is indicated in the poison-spray experiments described on page 65. Fifty per cent of newly emerged beetles were killed the first day, against 10 per cent of older beetles, both sets being subjected to identical conditions.

The feeding of the beetle is confined mainly to the upper surface of the leaves; the parenchyma is devoured, leaving characteristic chainlike feeding marks, as shown in Plate II. With individual beetles the length of time of feeding previous to egg deposition varies considerably. In Tables II and III is given the record of 16 individual females, showing a feeding period before oviposition varying from 9 to 24 days, with an average of 15.9 days.

TABLE II.—*Oviposition, feeding, and length of life of individual male and female beetles of Fidia viticida in captivity during the summer of 1909 at North East, Pa.*

Number of experiment	1.	2.	3.	4.	5.	6.
Date of emergence of beetles	June 30	June 30	June 30	June 30	July 2	July 2
Mated	July 8	July 8	July 8-9	July 14	July 13	....
First oviposition	July 22	July 21	July 15	July 21	July 15	July 19
Eggs	31	17	26	15	17	35
Second oviposition	July 25	July 26	July 16	....	July 28	July 26
Eggs	31	6	19	....	14	36
Third oviposition	July 26	....	July 27	....	Aug. 3	July 29
Eggs	40	....	14	....	5	31
Fourth oviposition	July 28	....	July 29	....	Aug. 8	July 31
Eggs	25	....	61	....	4	14
Fifth oviposition	....	....	....	....	....	Aug. 4
Eggs	....	....	....	....	....	14
Sixth oviposition	....	....	....	....	....	Aug. 7
Eggs	....	....	....	....	....	23
Seventh oviposition	....	....	....	....	....	....
Eggs	....	....	....	....	....	....
Eighth oviposition	....	....	....	....	....	....
Eggs	....	....	....	....	....	....
Ninth oviposition	....	....	....	....	....	....
Eggs	....	....	....	....	....	....
Death of male	Aug. 8	Aug. 26	Aug. 19	July 23	Aug. 25	....
Death of female	Aug. 1	Aug. 2	Aug. 3	July 23	Aug. 9	Aug. 31
Days of feeding before oviposition	22.0	21.0	15.0	21.0	13.0	17.0
Times of oviposition	4.0	2.0	4.0	1.0	4.0	6.0
Eggs per cluster:						
Minimum	25.0	6.0	14.0	15.0	4.0	14.0
Average	31.8	11.5	30.0	15.0	10.0	25.5
Maximum	40.0	17.0	61.0	15.0	17.0	36.0
Total number of eggs	127.0	23.0	120.0	15.0	40.0	153.0
Length of life of male	39.0	57.0	50.0	23.0	54.0	....
Length of life of female	31.0	32.0	33.0	23.0	38.0	60.0

TABLE II.—*Oviposition, feeding, and length of life of individual male and female beetles of Fidia viticida in captivity during the summer of 1909 at North East, Pa.*—Cont'd.

Number of experiment	7.	8.	9.	10.	11.	12.
Date of emergence of beetles	July 3	July 9	July 10	July 10	July 11	July 12
Mated	July 14	July 12 to 15	July 14	July 14	July 22	July 28
First oviposition	July 16	July 22	July 19	July 22	July 27	Aug. 3
Eggs	14	25	19	23	22	35
Second oviposition		July 25	July 20	July 26	July 29	
Eggs		51	35	48	15	
Third oviposition		July 28		July 27	Aug. 3	
Eggs		43		26	28	
Fourth oviposition		July 30		Aug. 3	Aug. 5	
Eggs		33		43	25	
Fifth oviposition		Aug. 2		Aug. 6	Aug. 8	
Eggs		28		24	11	
Sixth oviposition		Aug. 5			Aug. 9	
Eggs		21			11	
Seventh oviposition		Aug. 7				
Eggs		18				
Eighth oviposition		Aug. 8				
Eggs		15				
Ninth oviposition		Aug. 13				
Eggs		29				
Death of male	Aug. 25	Aug. 10	July 23	Aug. 14	Sept. 9	Aug. 14
Death of female	Aug. 23	Aug. 23	July 24	Aug. 26	Aug. 22	Aug. 6
Days of feeding before oviposition	13.0	13.0	9.0	12.0	16.0	22.0
Times of oviposition	1.0	9.0	2.0	5.0	6.0	1.0
Eggs per cluster:						
Minimum	14.0	15.0	19.0	23.0	11.0	35.0
Average	14.0	29.2	27.0	32.8	18.6	35.0
Maximum	14.0	51.0	35.0	48.0	28.0	35.0
Total number of eggs	14.0	263.0	54.0	164.0	112.0	35.0
Length of life of male	53.0	32.0	13.0	35.0	60.0	33.0
Length of life of female	51.0	45.0	14.0	47.0	42.0	25.0

Number of experiment	13.	14.	15.	16.	Totals.	Average.
Date of emergence of beetles	July 12	July 27	July 27	July 30		
Mated	July 27		Aug. 6			
First oviposition	July 28	Aug. 6	Aug. 7	Aug. 23		
Eggs	25	57	20	35	416	26.0
Second oviposition	Aug. 1	Aug. 8	Aug. 8	Aug. 26		
Eggs	22	43	22	20	362	27.8
Third oviposition	Aug. 3	Aug. 9	Aug. 13	Sept. 10		
Eggs	35	25	4	29	280	25.5
Fourth oviposition	Aug. 5	Aug. 13	Aug. 18	Sept. 14		
Eggs	19	8	39	23	294	26.7
Fifth oviposition	Aug. 7	Aug. 14	Aug. 23			
Eggs	16	37	28		158	22.6
Sixth oviposition	Aug. 11	Aug. 17				
Eggs	19	46			120	24.0
Seventh oviposition	Aug. 14	Aug. 19				
Eggs	18	16			52	17.3
Eighth oviposition	Aug. 19	Aug. 20				
Eggs	23	19			57	19.0
Ninth oviposition	Aug. 23					
Eggs	23				52	15.7
Death of male		Aug. 28	Aug. 14	Sept. 22		
Death of female	Aug. 25	Aug. 26	Aug. 27	Aug. 15		
Days of feeding before oviposition	16.0	10.0	11.0	24.0	255	15.9
Times of oviposition	9.0	8.0	5.0	4.0	71	4.4
Eggs per cluster:						
Minimum	16.0	8.0	4.0	20.0		
Average	22.2	31.4	22.6	26.7	383.3	24.0
Maximum	35.0	57.0	39.0	35.0		
Total number of eggs	200.0	251.0	113.0	117.0	1,791	112.0
Length of life of male		32.0	18.0	54.0	553	39.1
Length of life of female	44.0	30.0	31.0	16.0	562	35.1

TABLE III.—*Summary of oviposition experiments, recorded in Table II, showing the final average, maximum, and minimum, of egg deposition by individual female beetles in captivity, at North East, Pa., 1909.*

Observations.	Average.	Maximum.	Minimum.
Number of days previous to first oviposition	15.9	24	9
Number of times of oviposition	4.4	9	1
Number of days between ovipositions	3.6	15	1
Number of eggs per cluster	24.0	61	4
Number of eggs per female	112.0	263	14

In Table V (p. 30), giving records of experiments with a large number of beetles in stock jars, where only the minimum length of time could be verified, this feeding period is shown to have covered from 9 to 10 days. Feeding is continued for almost the entire length of life of the beetle, and it has undoubtedly a direct bearing upon the number of eggs deposited.

MATING AND ITS BEARING UPON EGG DEPOSITION.

Mating of beetles has been observed a few days after their emergence. It has been found to take place several times before the first egg deposition, the day previous to oviposition, and also after each oviposition. Repeated mating, however, is not essential in bringing about further egg depositions, as shown in one instance under observation (Table II, jar No. 13). In this jar the male and the female beetles were confined together shortly after emerging. Mating took place July 27, 28, and 30. The male beetle escaped August 5, yet oviposition by the same female occurred on August 7, 11, 14, 19, and 23 without further mating.

PROCESS OF EGG DEPOSITION.

As the time of egg deposition approaches, the female beetles cease feeding for a day or two and become sluggish and somewhat inactive. They generally seek the shady places and are at this period to be found on the canes of the vines, where they are less easily detected.

The eggs are deposited almost entirely under the loose bark on the canes and trunk; very rarely, however, they are placed on other parts of the vine. The female inserts the eggs beneath the loose bark by means of the protrusible ovipositor (fig. 11, *e*) and places them side by side in a cluster of a single layer. An adhesive substance, secreted by the female, glues the eggs together, and the entire mass is fastened either to the cane or to the inner surface of the loose bark (Pl. I, figs. 3, 4). Individual female beetles have been observed to move along the canes in search of suitable places for egg deposition. In this process the hind end of the body touches the cane, and as the insect slowly passes along the ovipositor is inserted into the cracks or crevices, apparently testing the fitness of these places for egg deposition. A female beetle is shown in Plate I, figure 1, photographed in the act of oviposition.

VARIATION IN THE NUMBER OF EGGS PER CLUSTER.

Under average conditions the eggs for each oviposition are all laid in a single cluster. In this respect exceptions occur when the female is disturbed in the act of oviposition or when the space is too small to hold all the eggs. On the other hand, it has been frequently found that eggs have been laid side by side by different females, so that from the appearance of the cluster separate depositions could not be told apart. In the breeding experiments clusters containing from 30 to 35 eggs have been found quite frequently, and these figures represent, approximately, the average number of eggs per cluster. Table II gives the egg deposition of 16 female beetles. As here there had been interference to some extent, and the beetles had been confined in captivity, the average number of 24 eggs per cluster was comparatively low. The maximum number of eggs in one cluster was 61 and the minimum 4 (Table III). In the rearing cages the period for each separate oviposition occasionally extended over from 1 to 2 days, rarely 3 days; normally, however, the eggs were all laid at once and in a single cluster.

NUMBER OF SEPARATE OVIPOSITIONS BY INDIVIDUAL FEMALES.

Different female beetles have displayed considerable diversity in the number of times of oviposition. In the experimental work 8 individuals failed to deposit any eggs; others, as recorded in Table II, oviposited from 1 to 9 times, or, on an average, 4 or 5 times. Similarly, the length of time between each oviposition is variable. An average of 4 days elapsed between each oviposition. Often the interval has been only 1 day, while in the other extreme in one case the interval was 15 days. (See Table IV.)

TABLE IV.—*Number of days between ovipositions of the grape root-worm as observed during 1909 in breeding cages at North East, Pa. (Supplementary to Table II.)*

No. of experiment.	Periods between ovipositions.								Total.	Average per female.
	I.	II.	III.	IV.	V.	VI.	VII.	VIII.		
1	3	1	2						6	2.0
2	5								5	5.0
3	1	11	2						14	4.7
4										
5	13	6	5						24	8.0
6	7	3	2	4	3				19	3.8
7										
8	3	3	2	3	3	2	1	5	22	2.7
9	4								4	4.0
10	4	1	7	3					15	3.7
11	2	5	2	3	1				13	2.6
12										
13	4	2	2	2	4	3	5	4	26	3.2
14	2	1	4	1	3	2	1		14	2.0
15	1	5	5	5					16	4.0
16	3	15	4						22	7.3
Total	52	53	37	21	14	7	7	9	200	53.0
Average	4.0	4.8	3.4	3.0	2.8	2.3	2.3	4.5		4.07

NUMBER OF EGGS DEPOSITED BY INDIVIDUAL FEMALE BEETLES.

The total number of eggs laid per female seems to depend upon the vitality of the individual insect, and undoubtedly also upon the amount of feeding by the adult. In the experiments of Table II the average was 112 eggs per female, with a maximum of 263 and a minimum of 14 eggs. In Table V is presented the results of the so-called "stock-jar" experiments, in which several beetles were confined.

TABLE V.—*Egg deposition of the grape root-worm by about 57 female beetles in eight stock jars, as observed in 1909 at North East, Pa.; with a summary of the length of life of the beetles for each stock jar.*

Stock jars.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	Total number of eggs.
Number of beetles.	25.	21.	5.	22.	16.	12.	7.	6.	
Date of the emergence.	July 9.	July 10.	July 11.	July 12.	July 13.	July 16.	July 19.	July 22.	
Date of oviposition:									
July 19...	85								85
July 20...		105							105
July 21...		33	13						46
July 22...	107	44	23	38	25				237
July 23...	70	21							91
July 25...	64				36				100
July 26...	96		21	68	33				218
July 28...	94	60	27		45				226
July 29...	43	39	25		74	41	31		253
July 30...	81			23					104
July 31...	22		29		13		35	10	109
Aug. 1....	121					39	3		163
Aug. 3....				35	36		143	26	240
Aug. 4....							26	16	42
Aug. 5....	28			52	14			22	116
Aug. 6....	60				28		70		158
Aug. 7....	35				38	23	66	77	239
Aug. 8....	33	10		152	29		36	22	282
Aug. 9....					34				34
Aug. 11...	17							38	55
Aug. 13...					16	10	18	12	56
Aug. 14...		16			22	37			75
Aug. 19...				19			23		42
Aug. 23...				21			21		42
Aug. 27...								23	23
Total oviposition	956	328	138	408	443	150	472	246	3,141
Eggs per female..	76.5	31.2	55.2	37.1	55.3	25.0	134.9	82.0	55.1

LENGTH OF LIFE OF BEETLES.

Maximum number of days	50	48	23	47	53	13	46	53	
Average number of days..	21.6	20.3	12.0	15.9	23.5	5.0	28.7	20.2	
Minimum number of days	6	5	4	3	2	3	6	1	

The number of female beetles for each jar has been estimated to be at least half of the total number placed therein. The average number of eggs per female for each separate experiment varied considerably. In jar 7 there were approximately 135 eggs per female, in jar 6 only 25 eggs per female, or a final average for the eight jars of only 55 eggs per female. In considering the average egg deposition in the breeding cages there were found to be about 75 eggs per female.

THE OVIPOSITION PERIOD FOR THE SEASON OF 1909.

The oviposition period and the number of eggs deposited for the entire season is directly influenced by the time of emergence and occurrence of the beetles. In Table VI is given the total egg deposition of beetles in captivity.

TABLE VI.—*Records of the total egg deposition of the grape root-worm in breeding cages at North East, Pa., during 1909.*

Date.	Eggs.	Date.	Eggs.	Date.	Eggs.	Date.	Eggs.
July 8	29	July 26	360	Aug. 6	291	Aug. 18	39
July 13	83	July 27	62	Aug. 7	353	Aug. 19	81
July 15	104	July 28	333	Aug. 8	397	Aug. 20	19
July 16	153	July 29	379	Aug. 9	102	Aug. 23	163
July 18	43	July 30	137	Aug. 10	19	Aug. 26	20
July 19	155	July 31	123	Aug. 11	74	Aug. 27	23
July 20	149	Aug. 1	185	Aug. 12	29	Sept. 3	40
July 21	88	Aug. 2	28	Aug. 13	101	Sept. 10	29
July 22	427	Aug. 3	421	Aug. 14	152	Sept. 12	22
July 23	121	Aug. 4	71	Aug. 16	26	Sept. 14	23
July 25	225	Aug. 5	223	Aug. 17	46	Sept. 20	15
Total	1,577	Total	2,322	Total	1,590	Total	474

Total number of eggs: 5,963.

With the exception of a few early records, which were obtained from beetles collected in the field June 30, these records represent the total oviposition by the greater proportion of the beetles emerging in breeding cages (listed in Table I), and for their entire length of life. As the date of the emergence of these beetles was normal and simultaneous with the occurrence of beetles under natural conditions in the field, it is thought that this record of egg deposition may closely approximate oviposition in vineyards. In considering the relative number of eggs laid at different dates, it will be found (Table VI; fig. 15) that previous to July 22, 13.5 per cent were deposited; from July 22 to August 8, 71.4 per cent, and after August 8, 15.1 per cent. Previously it has been shown how the time of emergence of the beetle varied, as a result of the development of the insect under different conditions. Thus oviposition in the same sections of the grape belt must differ under similar variations. The extreme of such variations has been especially marked in vineyards

located on the hill as compared with those in the valley. In Table XI is shown the time of hatching of eggs in the two named localities. On the hill the eggs were one week later in hatching, mainly as the result of later deposition.

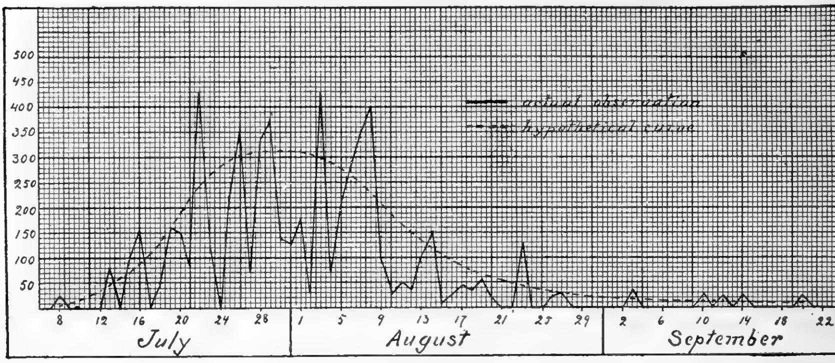


FIG. 15.—Curve showing time of egg deposition and relative abundance of eggs laid in rearing cages by beetles of the grape root-worm at North East, Pa., during 1909. (Original.)

LONGEVITY OF MALE AND FEMALE BEETLES.

On an average the beetles have lived in captivity one month. In Table VII will be found a full account of the length of life of individual male and female beetles.

TABLE VII.—*Length of life of individual male and female beetles of the grape root-worm as recorded in breeding cages at North East, Pa., during 1909.*

No.	Sex.	Date.		Days.		No.	Sex.	Date.		Days.	
		Emergence.	Died.	Male.	Female.			Emergence.	Died.	Male.	Female.
1	♂	June 30	Aug. 4	35	......	24	♀	July 10	Aug. 11	......	32
2	♀	...do....	July 22	......	22	25	♂	...do....	Aug. 6	27	......
3	♂	...do....	July 26	26	......	26	♀	...do....	Aug. 4	......	25
4	♀	...do....	July 27	......	27	27	♂	...do....	Aug. 14	35	......
5	♂	...do....	July 22	22	......	28	♀	...do....	Aug. 26	......	47
6	♀	...do....	July 21	......	21	29	♂	...do....	Aug. 23	44	......
7	♂	...do....	Aug. 19	50	......	30	♀	...do....	Aug. 24	......	45
8	♀	...do....	Aug. 3	......	34	31	♂	July 11	Aug. 22	42	......
9	♂	...do....	Aug. 8	39	......	32	♀	...do....	Sept. 9	......	60
10	♀	...do....	Aug. 1	......	32	33	♂	July 12	Aug. 9	28	......
11	♂	...do....	Aug. 26	57	......	34	♀	...do....	...do....	......	28
12	♀	...do....	Aug. 2	......	33	35	♂	...do....	Aug. 5	24	......
13	♂	...do....	July 22	22	......	36	♀	...do....	Aug. 25	......	44
14	♀	...do....	July 23	......	23	37	♂	...do....	Aug. 6	25	......
15	♂	July 2	Aug. 25	54	......	38	♀	...do....	Aug. 26	......	45
16	♀	...do....	Aug. 9	......	38	39	♂	June 15	Aug. 25	41	......
17	♂	...do....	Escaped.	......	......	40	♀	...do....	...do....	......	41
18	♀	...do....	Aug. 31	......	60	41	♂	July 27	July 28	1	......
19	♂	July 3	July 23	20	......	42	♀	...do....	Aug. 26	......	30
20	♀	...do....	July 24	......	21	43	♂	...do....	Aug. 14	18	......
21	♂	July 9	Aug. 10	32	......	44	♀	...do....	Aug. 27	......	31
22	♀	...do....	Aug. 23	......	45	45	♂	July 30	Aug. 15	16	......
23	♂	July 10	Aug. 27	48	......	46	♀	...do....	Sept. 22	......	54

The summary of these records (Table VIII) shows that the female beetles on an average, not individually, survived the males by 4 days.

TABLE VIII.—*Summary of the length of life of individual male and female beetles of Table VII.*

Sex.	Average.	Maximum.	Minimum.
	Days.	*Days.*	*Days.*
Male	32.1	54	1
Female	36.4	60	21

The maximum length of life for the males was 54 days, while that for the females was 60 days. In Table V is given further a summary of the length of life of the beetles in the stock jars, where no separate record has been made as to life of male and female individuals.

THE EGG.

INCUBATION PERIOD OF THE EGG.

The time necessary for the hatching of the eggs depends largely upon the prevailing temperature and probably also upon moisture conditions. Experiments to test the effective limits of these influences have not been made, but the results of these factors have been in a general way well marked as is evident from the difference in the time of hatching of individual egg clusters throughout the season (see Table IX). In different sections of vineyards the hatching probably varies slightly, since some eggs are located in well shaded places, while others are so situated as to receive more heat from the sunlight. In the middle of the hatching period eggs which were kept in an open outdoor shelter hatched, on an average, in 12 days. The rate for hatching for the entire egg period is shown in Table IX.

TABLE IX.—*Incubation period of eggs of the grape root-worm as observed in 1909 at North East, Pa.*

No. of observation.	Date.		Days.	No. of observation.	Date.		Days.
	Laid.	Hatched.			Laid.	Hatched.	
1	July 15	July 29	14	49	Aug. 7	Aug. 23	16
2	...do....	July 30	15	50	Aug. 8	Aug. 20	12
3	July 16	...do....	14	51	...do....	Aug. 21	13
4	July 18	July 31	13	52	...do....	Aug. 22	14
5	...do....	Aug. 1	14	53	...do....	Aug. 23	15
6	July 19	...do....	13	54	...do....	Aug. 24	16
7	July 20	...do....	12	55	Aug. 9	...do....	15
8	...do....	Aug. 2	13	56	...do....	Aug. 25	16
9	July 21	...do....	12	57	Aug. 10	...do....	15
10	...do....	Aug. 3	13	58	...do.....	Aug. 26	16
11	July 22	Aug. 2	11	59	...do....	Aug. 27	17
12	...do....	Aug. 3	12	60	Aug. 14	Aug. 26	12
13	July 23	Aug. 4	12	61	...do....	Aug. 27	13
14	July 25	Aug. 6	12	62	...do....	Aug. 28	14
15	July 26	...do....	11	63	...do....	Aug. 29	15
16	...do....	Aug. 7	12	64	...do....	Aug. 31	17
17	July 27	...do....	11	65	Aug. 16	...do....	15
18	July 28	Aug. 8	11	66	...do....	Sept. 1	16
19	July 29	...do....	10	67	Aug. 17	...do....	15
20	...do....	Aug. 9	11	68	...do....	Sept. 2	16
21	...do....	Aug. 10	12	69	...do....	Sept. 4	18
22	July 30	Aug. 9	10	70	...do....	Sept. 5	19
23	...do....	Aug. 10	11	71	Aug. 18	Sept. 4	17
24	...do....	Aug. 11	12	72	...do....	Sept. 5	18
25	...do....	Aug. 12	13	73	...do....	Sept. 6	19
26	July 31	Aug. 11	11	74	...do....	Sept. 7	20
27	...do....	Aug. 12	12	75	...do....	Sept. 10	23
28	Aug. 1	...do....	11	76	Aug. 19	Sept. 3	25
29	...do....	Aug. 13	12	77	...do....	Sept. 4	16
30	Aug. 2	...do....	11	78	...do....	Sept. 6	18
31	Aug. 3	...do....	10	79	...do....	Sept. 7	19
32	...do....	Aug. 14	11	80	...do....	Sept. 8	20
33	...do....	Aug. 15	12	81	...do....	Sept. 9	21
34	...do....	Aug. 16	13	82	...do....	Sept. 10	22
35	Aug. 4	Aug. 17	13	83	...do....	Sept. 11	23
36	Aug. 5	Aug. 16	11	84	...do....	Sept. 12	24
37	...do....	Aug. 17	12	85	Aug. 20	Sept. 6	17
38	...do....	Aug. 18	13	86	...do....	Sept. 7	18
39	...do....	Aug. 19	14	87	...do....	Sept. 8	19
40	Aug. 6	Aug. 18	12	88	...do....	Sept. 9	20
41	...do....	Aug. 19	13	89	Aug. 26	Sept. 18	23
42	...do....	Aug. 20	14	90	...do....	Sept. 19	24
43	...do....	Aug. 21	15	91	Sept. 3	Sterile.	....
44	Aug. 7	Aug. 18	11	92	Sept. 10	Sterile.	....
45	...do....	Aug. 19	12	93	Sept. 12	Sterile.	....
46	...do....	Aug. 20	13	94	Sept. 13	Sterile.	....
47	...do....	Aug. 21	14	95	Sept. 14	Sterile.	....
48	...do....	Aug. 22	15	96	Sept. 20	Sterile.	....

TABLE X.—*Summary of Table IX; time of incubation of grape root-worm eggs for 1909.*

Incubation.	Average.	Maximum.	Minimum.
	Days.	*Days.*	*Days.*
For the entire egg period....................................	14.67	24	10
For the maximum egg period, July 22–Aug. 8, inclusive......	12.3	16	10

Eggs laid at approximately the same date by the same female varied in the time of hatching to the extent of several days. The embryological development becomes particularly prolonged later in the season with the advent of colder weather. All the eggs laid during the month of September failed to hatch.

The rate of hatching of eggs in the field has been recorded in Table XI.

TABLE XI.—*Field observations on the hatching of eggs of the grape root-worm in the valley and on the hill in the vicinity of North East, Pa., 1909.*

In the valley.			On the hill.		
Date.	Number of clusters counted.	Percentage of clusters hatched.	Date.	Number of clusters counted.	Percentage of clusters hatched.
July 30...	41	39	July 30...	48	10
Aug. 4...	70	42	Aug. 13..	56	40
Aug. 12..	67	70	Aug. 19..	76	60
Aug. 19..	90	91	Aug. 26..	66	77
Aug. 26..	103	97	Sept. 2...	97	81
Sept. 2...	78	100	Sept. 9..	98	92
			Sept. 16..	87	100

THE LARVA.

VITALITY OF THE NEWLY HATCHED LARVA.

On hatching, the minute larva drops to the ground and makes its way to the roots of the vine through cracks and crevices in the soil and by burrowing. In this struggle to reach the food supply there is probably always a high percentage that perishes, for the number of eggs deposited is much larger than the number of larvæ found later in the ground.

The power of the young larva to exist for a time without food, however, is remarkable. In the breeding of the insect a number of newly hatched larvæ, confined in a glass tube, were kept alive for 8 days without food or moisture. Interesting experiments showing the burrowing and traveling powers of the young grub were carried out by Dr. E. P. Felt in 1902. This gentleman found that one larva had traveled a distance of over 47 feet in 7 hours, or an average of 6 feet an hour. In another experiment he found that 14 young larvæ out of 40 penetrated through loose earth in a glass tube 17 inches long in a period of 4 days. This tube was one-half inch in diameter and bent so that 4 inches were vertical. In our breeding cages young larvæ were found to feed upon the humus of the soil before reaching the root fibers; therefore it is not surprising that many larvæ do penetrate to the roots, even under unfavorable conditions, and that they are found in vineyards in compact clay soil.

FEEDING AND DEVELOPMENT OF THE LARVA BEFORE WINTERING.

During the summer and until late fall the larvæ feed extensively, and on an average attain three-fourths the full size and frequently full growth before wintering.

The young larva feeds mainly upon the finer roots and root fibers of the grapevine. Later it attacks the larger roots, devouring the bark in longitudinal furrows, as shown in Plate III. Sometimes the

feeding may even extend to the underground portion of the stem. Most of the larvæ are found within a distance of from 2 to 3 feet of the crown of the vine, and at a depth varying with the root system of the vines and the character of the soil.

The rate of growth of the larva varies under different conditions. The time of hatching, the abundance of food, and the ease with which food can be obtained are determining factors. As a rule the larvæ are found more abundantly in loose, porous soils, and especially on exposed ridges in the vineyards. (Table XII; fig. 14.)

TABLE XII.—*Occurrence of larvæ of the grape root-worm in different soils. Summary of field diggings for 1907, 1908, and 1909, at North East, Pa.*

Year.	Date of digging.	Total number of larvæ.	Number of vines examined.	Soil.	Number of larvæ per vine.
1907	May 13–June 8	831	66	Gravel	12
	May 31	1	7	Clay	0.1
1908	May 18–June 9	96	14	Gravel	6
	June 12	3	3	Clay	1
1909	May 24–June 25	539	88	Silt [a]	6
	May 19–June 25	439	83	Gravel	5
	May 27–July 10	102	37	Loam	3
	June 1–July 10	20	54	Clay	0.4

[a] Very light porous soil.

From rearing and field observations we have found that the larvæ are less abundant and slightly retarded in their development in clay soils. This is natural in that the larvæ can not move about to obtain food in this soil so readily as in soils of looser texture.

The growth of some larvæ is sometimes delayed to such an extent as to hinder them from transforming at the normal period in the spring. Hence these belated larvæ remain an additional year in the ground and transform in the spring of the second year. The causes of delay in the development and the percentage of belated larvæ have been described in detail on pages 41–44.

WINTERING OF THE LARVA IN AN EARTHEN CELL.

As the time for hibernation approaches the grubs penetrate deeper into the ground, generally slightly below the roots of the vines. An earthen cell is made in which the larva spends the winter. It was observed in the field in the fall of 1909 that the 2-year-old larvæ, referred to above, were the first to hibernate. Some of these were already in the wintering cells by the middle of August, when most of the larvæ of the new brood were still extremely small or had not yet hatched. In Table XIII is shown the relative occurrence of larvæ in wintering cells in the different vineyards. The actual percentage is higher than given, because in the process of digging many cells were broken, and thus escaped being noticed.

TABLE XIII.—*Percentage of hibernating larvæ of the grape root-worm as found in vineyards during the fall of 1909 at North East, Pa.*

Curtis vineyard, in the valley.		Algren vineyard, in the valley.		Young vineyard, on the hill.	
Date of digging.	Percentage of larvæ in cells.	Date of digging.	Percentage of larvæ in cells.	Date of digging.	Percentage of larvæ in cells.
Oct. 5	5	Oct. 4	0	Oct. 12	0
Oct. 12	20	Oct. 14	0	Oct. 20	3
Oct. 19	12	Oct. 19	14	Oct. 28	16
Oct. 28	83	Oct. 25	36	Nov. 12	33

SPRING FEEDING OF THE LARVA.

In the spring, with normally developed larvæ, comparatively little feeding takes place. In the early part of May, 1909, the larvæ in the rearing cages were still in their wintering cells, and the condition in the field in most places did not permit the larvæ to become active previous to that time. Since occasional pupal cells were found on May 24 in the field (Table XIV) and continued to appear in rapidly increasing numbers, the time of spring feeding may, on an average, have lasted 20 to 25 days.

TABLE XIV.—*Appearance of larvæ of the grape root-worm in cells previous to pupation at North East, Pa., 1909.*

Date of digging.	Soil condition.	Total number of larvæ.	Number of larvæ in cells.	Percentage of larvæ in cells.
May 19	Gravel	230		
May 24	Sandy	35	3	8.6
May 25	do	140	37	2.8
Do	Loam	33	7	21.2
May 26	Gravel	32	2	6.2
May 27	Clay	47	4	8.5
May 29	Silt	79	23	29.1
June 1	Clay	6		
June 2	Gravel	7	2	2.8
June 3	Silt	63	25	39.0
June 4	Gravel	54	10	18.5

TIME AND MAKING OF THE PUPAL CELL.

The pupal cells are found from 2 to 3 inches below the surface of the ground. Like the wintering cells, they are made by a peculiar rolling and twisting motion of the larva, whereby the cavity is enlarged, the earth becomes packed together, and the inside smoothly finished. The cell is quite spacious and would readily accommodate a larva twice the size of the owner. Usually 15 days are required to complete the pupal cell. As recorded in Table XVI, the average length of time spent by the larvæ in the cell is 21 days, which includes the post-larval stage described below. Should the cell be disturbed

or destroyed some time before the post-larval period, a new one is readily made, and, as a rule, within a shorter time than was required for the making of the first cell. As recorded in Table XV, individual No. 21, a larva made the second cell and pupated within 9 days.

Table XV.—*Observations on the transformations and habits of the pupa and the beetle of the grape root-worm in the soil, from breeding experiments at North East, Pa., 1909.*

Number of individual.	Date.				Days.		
	Making of cell.	Pupation.	Transformed to beetle.	Left the cell.	Making cell.	Pupal stage.	Beetle in cell.
1	May —	June 17	June 30	July 6		13	6
2	May —	do	July 1	(Died)		14	
3	May —	do	July 2	do		15	
4	May —	June 15	June 30	July 5		15	5
5	May —	June 20	July 7			17	
6	May —	June 19	July 9			20	
7	May —	June 21	July 10	July 14		19	4
8	May 30	do	do	do	22	19	4
9	do	June 20	July 2	(Died)	21	12	
10	May —	June 21	July 9	July 13		18	4
11	May 30	June 24	do	July 14	25	15	5
12	May —	June 20	do	July 13		19	4
13	May —	June 21	July 10	do		19	3
14	May —	do	do	July 14		19	4
15	May —	do	July 9	July 13		18	4
16	May 30	June 20	do	July 16	21	19	7
17	do	June 18	July 7	July 13	19	19	6
18	do	June 21	July 10	do	22	19	3
19	do	do	July 9	do	22	18	4
20	June 7	do	do		14	18	
21	do	do	July 6	July 13	9	20	7
22	May 30	June 16	July 12	July 16	25	18	4
23	June 7	June 24	July 11		14	20	
24	June 8	June 21	July 13	July 16	14	21	3
25	May 26	June 22	do	(Died)	31	17	
26	do	June 26	July 11	July 14	28	18	3
27	do	June 23	do	do	28	18	3
28	do	do	do	do	28	18	3
29		June 25	July 12	do		17	2
30	May 30	do	July 14	July 18	26	19	4
31	do	June 2	July 23		33	21	
32	do	June 22	July 10		23	18	
33	do	June 23	July 12		24	19	
34	June 4	June 25	July 11	July 17	21	16	6
35		June 26	July 14			18	
36		June 25	July 15	July 17		20	2
37		June 29	July 17			18	
38		June 21	July 8			17	
39	May 31	June 10			10		
40	June 5	June 23	July 11	July 15	18	18	4
41	June 8	do			15		
Total					513	696	104

Table XVI.—*The making of the pupal cell, the pupal period, the beetle in the cell; summary of Table XV.*

	Average.	Maximum.	Minimum.
	Days.	*Days.*	*Days.*
The making of the pupal cell	21.4	33	9
Pupal stage	17.8	21	12
Beetle in cell	4.1	7	2

THE POST-LARVAL STAGE.

During the post-larval stage the grub undergoes marked structural changes and is in this condition extremely delicate and helpless. The body is slightly shortened, and the curved grublike appearance is modi-

fied to a more cylindrical form. To some extent the legs become shorter and remain practically motionless. The white color changes to a light pinkish tint, which is especially marked toward the extremities. Should the cell be destroyed during this period the larva is incapable of making a new one, and in many instances, as has frequently been observed in the breeding experiment, the larva fails to pupate.

THE PUPA.

THE PROCESS OF PUPATION.

Pupation is the result of the changes brought about during the post-larval stage. In the process of pupation the larval skin splits on the back of the thorax and on the head, and the skin is ruptured along the median line and in front along the V-shaped suture toward the mouth (fig. 8, *b*). As the pupa frees itself from the larval skin it is of a rather elongated form. The appendages are short, and the skin on these parts is wrinkled in a circular manner. The light pink color is particularly marked on portions around the spines, head, prothorax, the points of the legs, and on the hind end of the body. The pupa is at this stage very restless, turning the abdomen in a circular motion, which, together with a contracting motion, brings about the expansion of the appendages and the assuming of the normal shape of the pupæ. Unlike many pupæ of beetles of this group, the larval skin is completely freed from the pupa. Within a short time the pupa becomes whiter in color and the prominent spines turn darker as they harden.

POSITION OF THE PUPA IN THE CELL.

Within the cell the pupa is continually moving, often changing its position and constantly turning the abdomen in a circular manner. Normally the pupa lies on its back, and the soft body of the tender creature is kept from close contact with the moist walls of the cell by the spines on the appendages and on the back of the body (fig. 9). This function of the spines is undoubtedly of great importance in the development of the pupa, since this is the critical period of the insect, when the organs and in fact all the parts of the insect are reconstructed in the formation of the adult or beetle. The pupa is completely helpless when removed from the cell and is incapable of making a new one, and if left on the surface of the ground or covered up with earth it almost invariably perishes.

TIME OF PUPATION IN THE FIELD AND IN BREEDING CAGES.

In the field during the summer of 1909 the first pupæ were found June 11, while in the breeding cages the first pupa was found June 15. The time of pupation is indicated in Table XVII, showing the relative occurrence of the pupæ in the field.

TABLE XVII.—*Time of transformation of larvæ and pupæ of the grape root-worm in the field, as observed in the vicinity of North East, Pa., 1909.*

Vineyard.	Date examined.	Number of vines examined.	Number of larvæ.	Number of pupæ.	Number of beetles in cells.
J. D. Curtis's vineyard, porous silt.	June 12	....	286	32	....
	June 21	7	6	47	....
	June 25	6	2	54	2
	June 30	6	2	4	24
	July 6	6	....	....	4
	July 10	6	....	....	....
G. E. Pierce's vineyard, gravel soil.	June 11	....	101	49	....
	June 21	6	5	13	....
	June 25	6	5	12	....
	June 30	6	....	....	3
	July 6	7	....	....	2
	July 10	6	....	....	....
Vineyard, loamy soil.	June 23	6	3	24	....
	June 25	6	1	5	....
	June 30	6	1	17	2
	July 7	6	1	2	2
	July 10	6	....	1	1
	July 17	6	....	....	....
Whitman's vineyard, clay soil.	June 23	6	1	6	....
	June 25	6	1	5	....
	June 30	6	1	2	....
	July 7	6	1	....	1
	July 10	6	....	1	....
	July 17	6	....	....	1
	July 26	6	....	....	....

It is possible to establish the time of pupation by knowing the time of emergence of the beetle and the length of time of the pupal stage. Judging by the late emergence of the beetles, August 9, and by the finding of beetles in cells in the field August 14, pupæ must have occurred up to the end of July. Based upon these records the curve of figure 23 has been constructed.

DURATION OF THE PUPAL PERIOD.

The pupal stage on an average lasts 17 days (see Tables XV and XVI). The maximum length of time observed was 21 days and the minimum 12 days.

LIFE CYCLE OF THE GRAPE ROOT-WORM AS DETERMINED BY REARING.

Several attempts were made to rear this insect from eggs, and to carry it through the different stages to complete the life cycle. In the course of these experiments many failures occurred. The mortality in certain experiments was high; in other instances a large percentage became materially delayed in development and the larvæ wintered a second season, and only a small number completed the life cycle within one year. (See Table XX.) The records from these latter observations are given in Table XVIII, with dates of hatching in 1908 and the dates of reaching maturity the following year.

TABLE XVIII.—*Complete life cycle of 19 grape root-worms at North East, Pa., reared from eggs laid during 1908; adults emerged in 1909.*

Number of individuals.	Date of Hatching of eggs, 1908.	Date of Emergence of beetles, 1909.	Number of days for the life cycle.
1	July 16	July 9	358
1	...do.....	July 10	359
1	...do....	July 13	362
1	...do....	July 15	364
1	...do....	July 17	366
4	July 20	July 7	352
1	...do....	July 8	353
4	...do....	July 10	355
2	...do....	July 11	356
1	...do....	July 30	375
1	July 25	July 26	366
1	...do....	July 27	367
19	....	....	6,810

SUMMARY.

	Days.
Average	358.4
Maximum	375
Minimum	352

SEASONAL VARIATIONS IN THE LIFE HISTORY OF THE GRAPE ROOT-WORM.

In comparing the records for the time of emergence of the beetle for the three consecutive years of 1907, 1908, and 1909 a marked difference in the date of emergence will be found (fig. 16). This variation is partly due to the relative lateness of the spring and partly to the climatic conditions prevailing during the entire development of the insect in the ground.

The climatic conditions for the years 1906 to 1909, inclusive, have been strikingly varied and, as will be seen, the life of the insect for these years has been affected accordingly. The mean temperature for 1906 was 1 degree above normal and the precipitation averaged about 1 inch below normal, August and September being particularly dry and hot. Frost occurred June 11 and 12 and snow on October 10, 11, and 12. The year 1907 was marked with an abnormally low temperature, a late spring, and an early fall, with a rather high precipitation for the summer months. The month of May was the coldest on record during a period of eighteen years. In 1908, on the contrary, the mean temperature was above normal and the summer was marked by two periods of severe drought, the dry conditions being especially felt during the end of August. In most respects 1909 (fig. 17) was nearer the average.

Although 1906 was a favorable season, during which the larvæ attained a normal growth, yet owing to the late and cold spring of 1907 the emergence of the insect was very materially delayed and

limited to a very short period (see fig. 16). The first beetle in the field was observed July 11. In the spring of 1908, on collecting larvæ in different vineyards two distinct sizes were found, as possibly due to climatic conditions of previous seasons. The larger larvæ were full grown, while the smaller varied from one-third to three-fourths grown. In the rearing cages the full grown larvæ transformed normally and without further feeding. Of the smaller larvæ few matured at the normal time, many were quite belated, while quite a number wintered, thus spending two years as larvæ in the ground. As a result of the early season of 1908 the beetles commenced to emerge by June 16. The emergence extended over a long period;

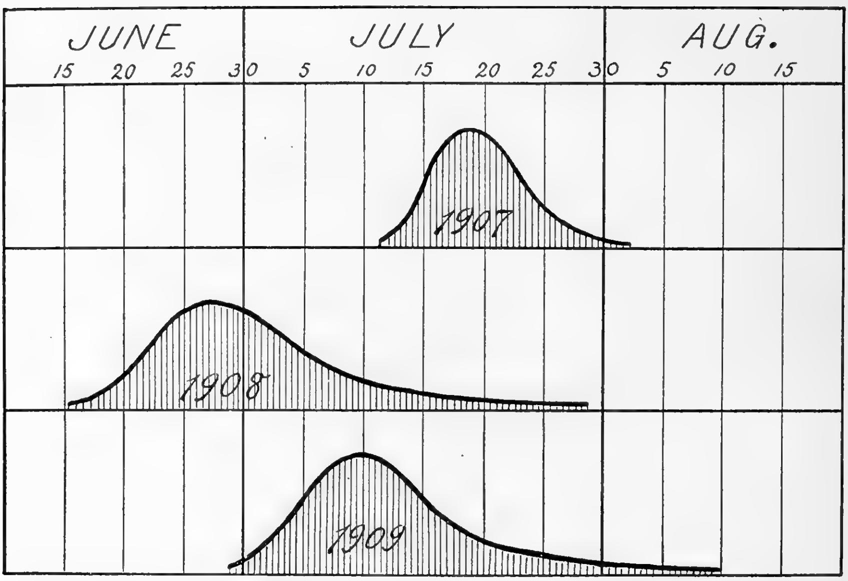


FIG. 16.—Diagram showing variation in time of emergence of beetles of the grape root-worm during 1907, 1908, and 1909 at North East, Pa. (Original.)

the latest beetles to emerge appeared in the rearing cages July 28. This longer emergence period was partly due to the delay in the development of larvæ that hatched in 1907. In the spring of 1909 the larvæ were again of a more uniform size as a result of the long season of 1908, and the emergence in 1909, as recorded in figure 16, was about normal. On examining larvæ in the field in the early fall of 1909 data were obtained as to the prevailing number of 1-year and 2-year old larvæ (Table XIX). At the dates of these observations only a few of the new-brood larvæ had attained one-half their growth while many of the eggs had not yet hatched, and since the 1908 brood larvæ were full grown the two broods could then be readily told apart.

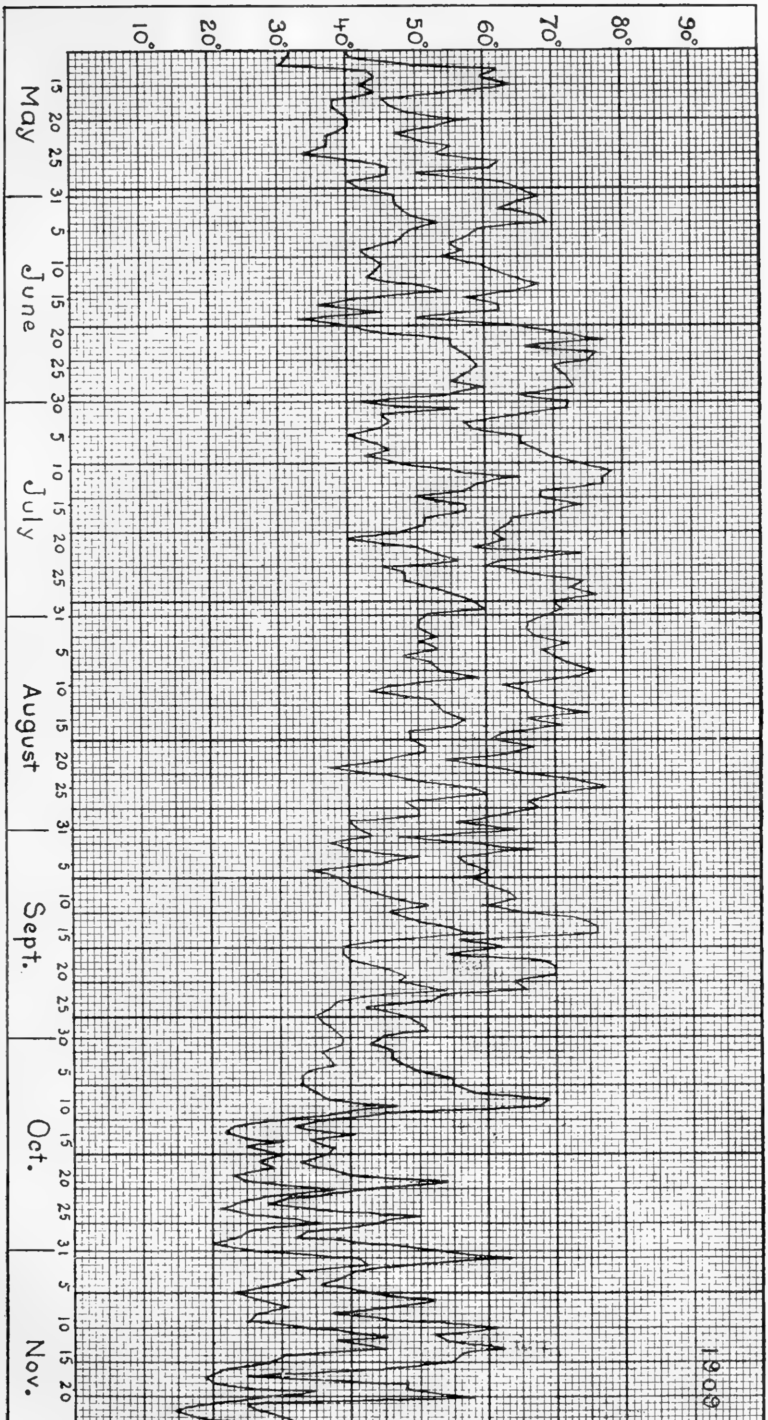


FIG. 17.—Temperature curves showing the daily records of the maximum and minimum temperature during the breeding period of 1909 at North East, Pa. (Original.)

TABLE XIX.—*Percentage of 2-year-old larvæ of the grape root-worm as recorded in vineyards in the vicinity of North East, Pa., in the fall of 1909.*

Vineyard in silt soil in the valley.				Vineyard on loamy soil in the valley.				Vineyard on gravelly loam on the hill.			
Date of digging.	Number of vines examined.	Total number of larvæ.	Percentage of old larvæ.	Date of digging.	Number of vines examined.	Total number of larvæ.	Percentage of old larvæ.	Date of digging.	Number of vines examined.	Total number of larvæ.	Percentage of old larvæ.
Aug. 17 to Oct. 12	32	328	3.0	Aug. 16 to Sept. 20	18	449	0.66	Sept. 2 to Oct. 7	11	517	5.0

The percentages of twice-wintering larvæ in Table XIX represent only records of early observations when a number of larvæ had not yet been hatched. It is of interest to note that the percentage of 2-year-old larvæ was largest in vineyards located on the hill, owing to the prevailing shorter season on the hill as compared with the season in the valley. The time of transformation of the insects in other stages has similarly been affected by the climatic conditions of the past three years.

In Table XX is shown the relative number of maturing insects and twice-wintering larvæ which were reared from eggs deposited at known dates in 1908.

TABLE XX.—*The relative occurrence of transforming and twice-wintering larvæ of the grape root-worm reared from eggs laid in cages in 1908, at North East, Pa.*

Date of hatching 1908.	Number of beetles emerging, 1909.	Number of larvæ wintering, 1909.
July 16	5	12
July 20	12	0
July 25	2	0
July 28	0	3
Total	19	15

In the rearing experiments other factors beside climatic conditions have influenced the results and no direct conclusion should be drawn from these observations beyond the point of establishing the fact that under unfavorable conditions individual insects of this species do remain two years in the ground before maturing.

REARING AND EXPERIMENTAL METHODS.

The underground habits of the larvæ of the grape root-worm have made the rearing of this insect comparatively difficult, and certain obstacles have been overcome only by persistent and continued experimenting. The rearing work in most cases has been planned

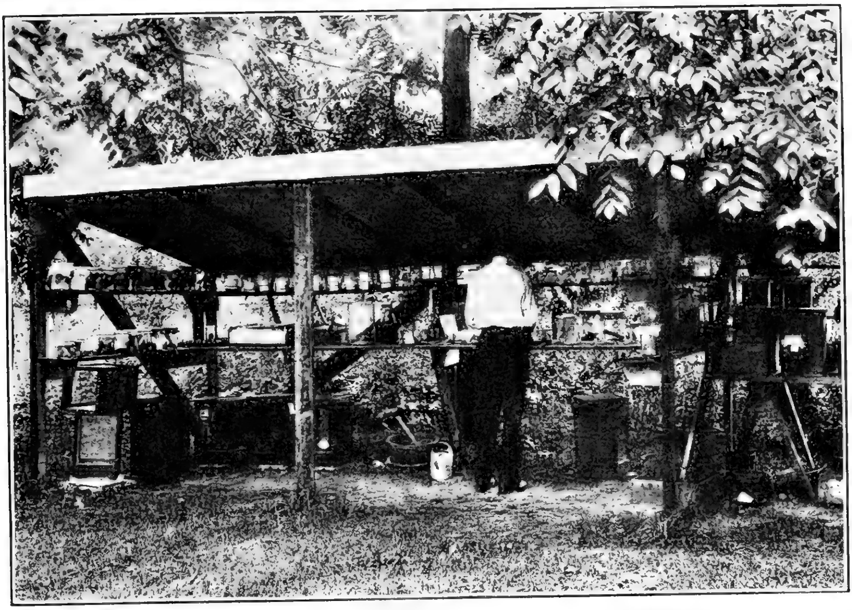


FIG. 18.—Portion of the outdoor rearing shelter used in the rearing of insects at North East, Pa., during 1909. (Original.)

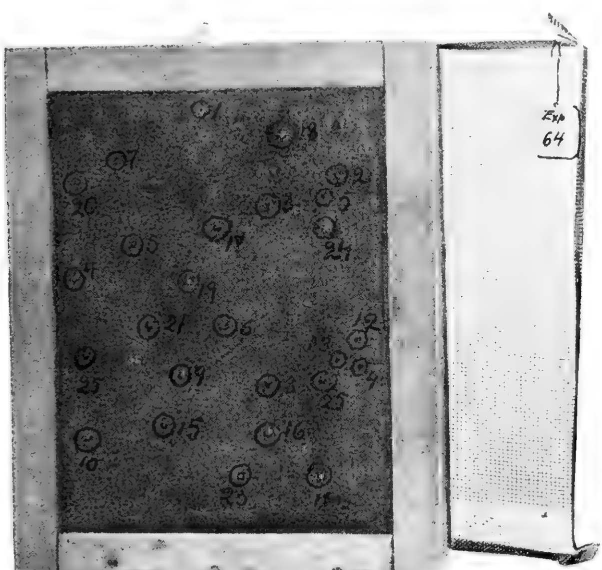


FIG. 19.—Wooden-frame box with glass bottom and wire-screen cover used in studying the pupal stage of the grape root-worm beetle. (Original.)

on a large scale, so that variations would be minimized and the final averages would represent approximately normal conditions. The numerous separate experiments have involved the handling of a large bulk of rearing material, which, together with the simulation of normal conditions, has to some extent necessitated special rearing devices and methods of handling. The experiments have been con-

FIG. 20.—Earthen pot with glass cylinder used in rearing the grape root-worm. (Original.)

ducted either in the field or under an open breeding shelter, a portion of which is shown in figure 18. This consisted of a temporary structure of light wooden framework covered with waterproof canvas.

Most of the rearing material was obtained in the spring, some time previous to the transformation of the larvæ. During the past two years of the investigation the insects were to some extent reared

from eggs laid in the cages, and these larvæ, together with larvæ of the previous year, were carried through the winter in rearing cages.

The pupal records have been obtained from experiments in medium-sized wooden boxes, having glass bottom, 9 inches long, 8 inches wide, and 5 inches high (fig. 19). Each box contained 2 to 3 inches of earth, and in order to duplicate outside weather conditions as nearly as possible the soil in these boxes was permitted to become almost dry during dry periods and during rainy periods water was proportionately added. To exclude the light from below, the boxes were placed upon burlap. Previous to the emergence of the beetles a wire screen cover was placed over each box. The shallow layer of soil caused many larvæ to penetrate to the bottom of the cages, where they appeared next to the glass; and as the pupal cells, made of earth packed together, were next to the glass the activity of the insect inside could be readily observed. By means of a glass and porcelain blue pencil a number was fixed next to each cell, and by using this number a detailed record could be kept from the time the cell was made to the time the adult emerged. In the study of the underground habits of the insect the device shown in figure 20 proved to be useful. The glass cylinder in the earthen pot was about half filled with soil, and to exclude the light the lower portion of the cylinder was wrapped with black paper. Several cells were made next to the glass, and on emerging the beetles were observed in the process of making their exit through the soil.

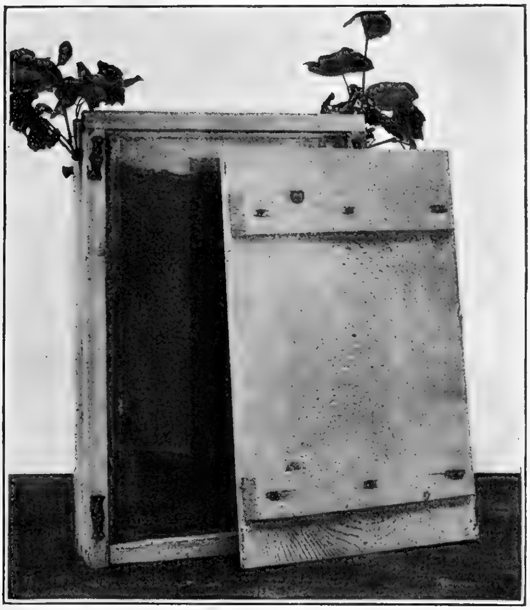


FIG. 21.—Rearing cage with glass sides used in the study of the larva of the grape root-worm beetle. (Original.)

Cages similar to the one shown in figure 21 were convenient for the study of the habits of the larva, and they were particularly useful in experiments extending over periods of one and two years. In width

these cages varied from 1 to $2\frac{1}{2}$ inches, and were of a uniform height of 20 inches. The two larger sides consisted of plate glass with outer wooden shutters on either side which could be removed for the examination of the contents.

The emergence records of Table I, as shown by curve in figure 13, are the results of about 15 separate experiments with larvæ transforming in large earthen pots filled with soil. Since the time of emergence of the beetles and their relative occurrence has a direct bearing upon the time of application of poison sprays against this pest, special attention and care were exercised in preparing these experiments. In the early spring approximately 1,000 larvæ were collected in different vineyards in the vicinity of North East, Pa. In many instances soil from different localities, which varied from loose sandy soils to heavy clay, was transferred with the larvæ to the rearing pots (fig. 22). Provision for the spring feeding of the larvæ was made by planting young grapevines in the pots. Finally the pots were placed in the ground in the open field and were left undisturbed for the rest of the season. Before the beetles commenced to appear wire screen covers were placed over each pot, so that a complete daily record could be kept of the number of beetles emerging from each separate pot.

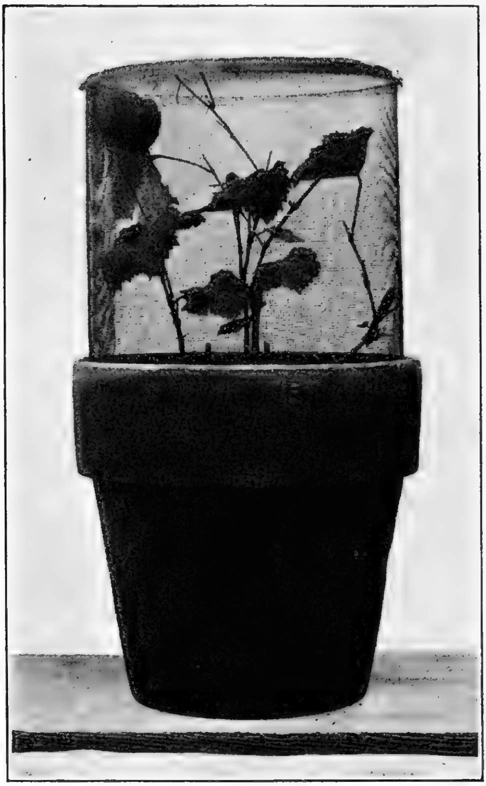


FIG. 22.—Earthen pot with wire-screen cover used in rearing the grape root-worm. (Original.)

By preserving the beetles from the above-mentioned experiments, rearing material of known source and age was obtained for further experiments. The daily catch of beetles throughout the emergence period was transferred to so-called "stock jars," from which insects were taken as needed for miscellaneous experiments. The "stock jars" shown in the rearing shelter (fig. 18) consisted of large-sized glass jars covered with thin cloth. A layer of moist sand was placed

in each jar, which made it easier for the insects to move about and made the conditions more natural. Grape foliage, constituting the food of the beetles, was supplied daily, and to prevent unhealthy conditions in the cages the old leaves were always removed. For oviposition short pieces of grapevine cane were placed with the beetles, and as egg depositions progressed these canes were removed daily and replaced by fresh ones. In determining the number of eggs deposited, the loose bark had to be peeled off the pieces of cane and the eggs in each cluster carefully counted. In determining the egg deposition of individual females and the length of life of male and female beetles, pairs when found in ·opulation in the stock jars were

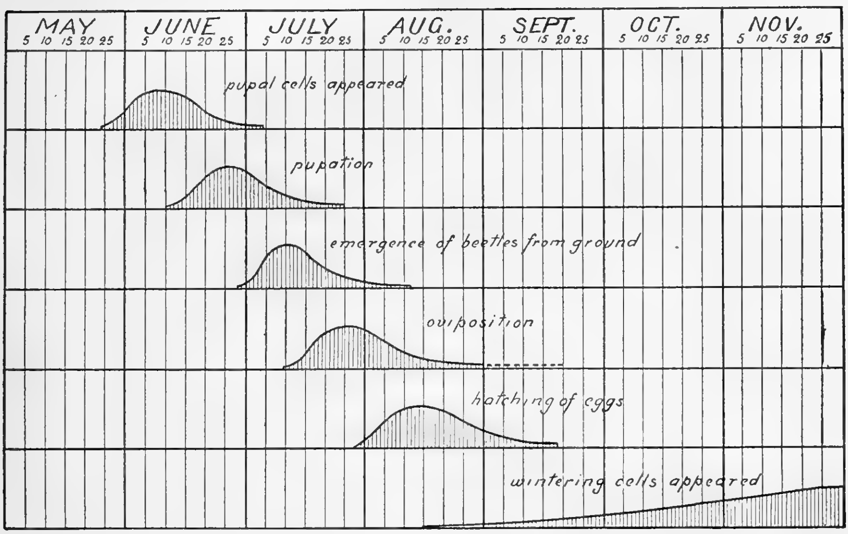


FIG. 23.—Diagram illustrating seasonal history of the grape root-worm as observed during 1909 at North East, Pa. (Original.)

isolated previous to the earliest egg deposition. The observations on the habits of these individual beetles are given in Table II.

Since the greater portion of the beetles from the emergence cages was used in obtaining the egg records, and since these insects oviposited undisturbed during the entire season, it is believed that the records in figure 15 represent the relative occurrence of eggs in the field.

Eggs used in determining the length of time of incubation were kept in glass tumblers under the outdoor breeding shelter.

In conjunction with the rearing work, field observations were constantly made, and in certain instances collections of the insect in its different stages were regularly made in the same localities for a given length of time. Thus it has been possible to check the rearing obser-

vations with field conditions, and whenever differences have occurred corrections in the summary (fig. 23) have been made to approximate field conditions.

SUMMARY OF LIFE-HISTORY STUDIES OF THE GRAPE ROOT-WORM.

The life history of the beetle (see fig. 12, p. 23) may be briefly summarized as follows: The grape root-worm produces only one generation a year; the larva feeds on the roots of the grapevine, and in this stage the insect is found in the ground for the greater part of the year. In early June the full-grown larva makes an earthen cell a few inches below the surface of the ground, within which it pupates about the middle of June; the pupal stage lasts generally twenty days, and the beetle or adult begins to emerge from the ground in late June or early July, while a few belated beetles continue to appear in the early part of August. On an average the beetle feeds for from 10 to 13 days on the grape foliage before ovipositing. The eggs are laid beneath the loose bark on the canes of the vines, and hatch on an average in 12 days; the young larva drops to the ground and soon finds its way to the roots of the vine; generally the larva becomes three-fourths grown and sometimes attains its full growth in the fall. Previous to wintering it penetrates deeper into the ground, below the roots, and there constructs an earthen cell in which it passes the winter.

The diagram (fig. 23) shows the relative occurrence and the time of transformation of the grape root-worm in its various stages. It has been prepared from field observations and rearing records of 1909 and is a summary graphically presenting the life-history studies.

Local variations in the times of development of the different stages of the insect, as described in preceding pages, may be brought about by various factors, such as differences in the texture of the soil, relative abundance of food, and altitude and exposure of vineyards. The seasonal variations, as shown by the difference in the time of emergence of beetles during 1907, 1908, and 1909, and also by the occurrence of larvæ that remained two winters in the soil, are the direct results of climatic influences. The insect has a strong tendency, however, to develop normally, even under adverse conditions.

NATURAL ENEMIES.

PREDACEOUS INSECTS.

Several predaceous insects have been found feeding upon the larvæ of the grape root-worm. During the process of digging for larvæ, both in the spring and fall, various species of carabid beetles and their larvæ have been found in the ground. These insects are entirely predaceous and probably feed upon the grubs of the grape root-worm whenever the latter come within their reach. Dr. E. P. Felt recorded

Staphylinus vulpinus Nordm. as probably predatory on the larvæ. In the spring of 1909 in one instance a "June-bug" larva (*Lachnosterna* sp.) was found by the junior writer feeding upon a larva of the grape root-worm beetle. When first discovered the grape root-worm was already half devoured, and while the operation was being watched the remaining portion was completely eaten.

The eggs of the grape root-worm are subject to the attacks of a number of different predaceous insects. Professor Webster observed in Ohio a small brown ant (*Lasius brunneus* Latr. var. *alienus*) and three species of mites (*Tyroglyphus* [*Rhizoglyphus*] *phylloxeræ* [Riley], *Heteropus* [*Pediculoides*] *ventricosus* Newport, and the third, resembling *Hoplophora* [*Phthiracarus*] *arctata* Riley), feeding upon the eggs. Mr. P. R. Jones, of this Bureau, in 1907, at North East, Pa., found a coccinellid larva (*Hippodamia convergens* Guér.), and a malacoderm larva (family Telephoridæ) feeding upon the eggs of the grape root-worm. The determinations of these coleopterous larvæ were made by Mr. E. A. Schwarz, of this Bureau. The junior author in 1909, at North East, Pa., collected a small ant, determined by Mr. Th. Pergande, of this Bureau, as *Cremastogaster lineolata* Say, var.?, which carried off eggs from a cluster on a grape cane. The larvæ of a lace-wing fly (*Chrysopa* sp.) have been observed from time to time extracting the egg contents by means of their pointed, tubelike mandibles, which are peculiarly well fitted for the purpose.

PARASITIC INSECTS.

Two minute hymenopterous egg parasites, *Fidiobia flavipes* Ashm. and *Lathromeris* (*Brachysticha*) *fidiæ* (Ashm.), were reared from eggs of the grape root-worm in Ohio by Professor Webster. The late Professor Slingerland recorded *Fidiobia flavipes* in the Lake Erie section in 1900, and later, during the present investigation by the Bureau of Entomology at North East, Pa., this minute egg parasite has been constantly noticed by different members of the staff. *Lathromeris fidiæ* (Ashm.) has been only once observed at North East, Pa., as recorded on pages 56–57. The two parasites mentioned above were described by the late Dr. William H. Ashmead[a] in 1894 from specimens reared by Prof. F. M. Webster. The original description of Fidiobia is given herewith:

Fidiobia flavipes sp. n. Female, length, 0.6 mm. Black, polished; legs and antennæ yellow; thorax without distinct furrows, smooth, with only slight indications of furrows posteriorly, but not sharply defined; wings hyaline, veinless; abdomen oblong, sessile, the first segment wider than long, the second very large, occupying most of the remaining surface, the following being usually retracted with it, and thus making the abdomen appear truncated at apex.

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[a] Cinti. Soc. Nat. Hist., vol. 17, 1894, pp. 170–172.

LIFE HISTORY OF FIDIOBIA FLAVIPES ASHM.

During the summer of 1909 the junior author had opportunity to rear *Fidiobia flavipes* Ashm. (fig. 24) and to make some observations relative to its habits and occurrence in the Lake Erie grape belt.

The parasitized root-worm eggs can be readily recognized in that they assume a brownish-yellow cast and become gradually darker with the development of the parasite. The grape root-worm eggs when first deposited are whitish, but soon take on a yellowish cast. In view of the semitransparent eggshell it is possible to observe the development of the different stages.

Parasitized eggs were obtained in the vineyards July 13, from which adults issued on August 3. These adults were then placed in a vial August 4, with fresh eggs which had been laid in breeding cages the previous day. On August 7 an irregular area could be distinguished in the center of each egg, indicating a breaking up of the yolk tissue. On August 11 the parasitized eggs were already of a dark yellowish-brown cast. In one extremity of the egg there began to appear an empty space and the larva could be distinguished feeding toward the opposite end. On August 14 most of the parasite larvæ pupated. Two or three days after pupation the eyes could be distinguished in the form of black spots, and a few days previous to the time of the emergence of the adults the entire pupa assumed a dark color. The minute hymenopterous flies emerged August 28, 29, and 30.

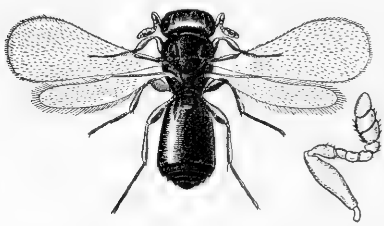


FIG. 24.—*Fidiobia flavipes*, an egg-parasite of the grape root-worm: Adult and enlarged antenna. Very greatly enlarged. (Original.)

In summarizing these data, we get 10 days for the egg and larval stages, 14 to 15 days for the pupal stage, or a total of 24 to 26 days for the whole life cycle. It is possible to recognize parasitized eggs 3 or 4 days after they become infested. Adult insects lived from 5 to 7 days in a test tube without food.

To determine the development of parasites from root-worm eggs of different ages and also to test in a general way the resistance of eggs of different ages to parasitism, the following experiments were carried out as summed up in Tables XXI and XXII:

TABLE XXI.—*Parasitism of grape root-worm eggs by Fidiobia flavipes at North East, Pa., 1909, the eggs ranging in age from 1 to 9 days.*

Observation.	Grape root-worm eggs.		Hatched.	Parasitized.
	Oviposition.	Normally hatching.		
1	July 30	Aug. 11	×	....
a2	July 31	Aug. 12	×	×
3	Aug. 1	Aug. 13	....	×
4	Aug. 3	Aug. 14	....	×
5	Aug. 4	Aug. 17	....	×
6	Aug. 5	...do....	....	×
7	Aug. 6	Aug. 21	....	×
8	Aug. 7	Aug. 24	....	×
9	Aug. 8	Aug. 26	....	×

a Parasites placed with the host August 9. New parasites emerged September 10 to 12. Thirty-two to thirty-four days to complete the life cycle. Experiment No. 2 consisted of 15 root-worm eggs, of which 13 became parasitized and 2 eggs developed root-worms normally. Eggs within two to three days of hatching escaped parasitism.

TABLE XXII.—*Parasitism of eggs of the grape root-worm by Fidiobia flavipes, at North East, Pa., 1909, eggs varying in age from fresh to 10 days old.*

Number of observation.	Root-worm eggs.		Number of eggs.	Emerging root-worm larvæ.	Hatching of parasites.
	Oviposition.	Normally hatching.			
1	July 25	Aug. 6	15	15	....
2	July 26	Aug. 7	20	20	....
3	July 28	Aug. 8	38	....	37
4	July 30	Aug. 10	13	....	12
5	Aug. 1	Aug. 11	18	....	18
6	Aug. 2	Aug. 13	19	....	19
7	Aug. 4	Aug. 14	22	....	21

Parasites placed with host August 4, having emerged August 3. New adults emerged August 30 to September 3. Twenty-seven to thirty-one days to complete the life cycle. Root-worm eggs within two to three days of hatching escaped parasitism.

For each experiment egg clusters of the grape root-worm, each of a given age, ranging from 1 to 10 days, were subjected to the parasites. The insects with the host were confined in large-size glass vials, which were covered with fine cloth. In Table XXI it is probable that the parasites oviposited shortly after being confined with the host, since they had emerged a few days previous to their confinement with fresh eggs. In the first experiment (Table XXI) the parasites were confined three days with the hosts. The two experiments of Tables XXI and XXII are practically identical, the second being made to check the results with those of the first one. The records for the normal hatching of the eggs are from another set of records, since such data could not be obtained from parasitized eggs. The results of either experiment show that the parasites did not affect eggs which were within two or perhaps three days of hatching. There was no marked difference in the time of the development of the parasites from eggs of different ages.

The percentage of parasitized eggs in the field varied considerably in different sections of the grape belt, as well as in parts of the same vineyard. It was always highest where eggs were most numerous. This was especially brought out in the different sections in the experimental vineyards, where the sprayed areas were but slightly infested with root-worms.

Thus, Davidson's vineyard, consisting of 12 acres, located half a mile north of the city, showed in 1908 the following results:

	Per cent parasitized.	Average number of eggs per vine.
Unsprayed young Concord vines	18	268.8
Sprayed young Concord vines	9.5	12.4
Unsprayed old Concord vines	13.2	319.2
Sprayed old Concord vines	20	23.6
Unsprayed Niagara vines	35	56.0
Sprayed Niagara vines	Free.	1.2

The Porter vineyard, located a few miles east of the town and containing 10 acres of old Concord vines, gave the following results:

Unsprayed plat had 14.7 per cent parasitized eggs.
Sprayed plat had 5.5 per cent parasitized eggs.

By comparing the records taken during August from three different vineyards located within a radius of from 2 to 3 miles east of N rth East, Pa., Algren's vineyard on August 4 showed 2 per cent of parasitized eggs; Young's vineyard, August 24, showed 16 per cent; and Wheeler's vineyard, August 27, 96 per cent.

A marked increase of parasitism was observed with the advancement of the season. The records given below, obtained by H. B. Weiss, from Mr. Young's vineyard, illustrate this fact:

	Per cent.
July 30	5
August 13	10
August 19	14
August 26	16
September 2	20

Similar records from other vineyards were not as uniform as those just given, but since the percentage varies with the amount of eggs present, no great uniformity can be expected unless the eggs are found more or less evenly distributed in the vineyards.

By breeding the parasites two full generations and a partial third were produced. Infested eggs were obtained in the field July 13, from which adults emerged August 3. These were placed with fresh eggs August 4, and new adults issued August 28. The third generation developing from these adults was much delayed by cold weather, but at the time of concluding the field work for the season on November 22 the adults were about to emerge.

The diagram (fig. 25) shows the relation of the three generations of parasites as observed in the breeding cages to the time of oviposition and the time of hatching of the host eggs. With the data in hand it is not possible to determine the period covered by each generation. The records only show the appearance of the first adults for the three generations. A few conclusions can, however, be drawn from the above diagram. Adult parasites must have existed in vineyards at the time of earliest oviposition of the grape root-worm. Adults producing the second generation appeared before the greater portion of the root-worm eggs had hatched, and since eggs could become parasitized within two days of hatching, the second generation is apt to infest more eggs than either the first or the third generation. In fact, the third generation appeared so late that it only reached a very few belated eggs.

Fidiobia flavipes is an important factor in the control of the grape root-worm. Professor Webster, who for several years studied the

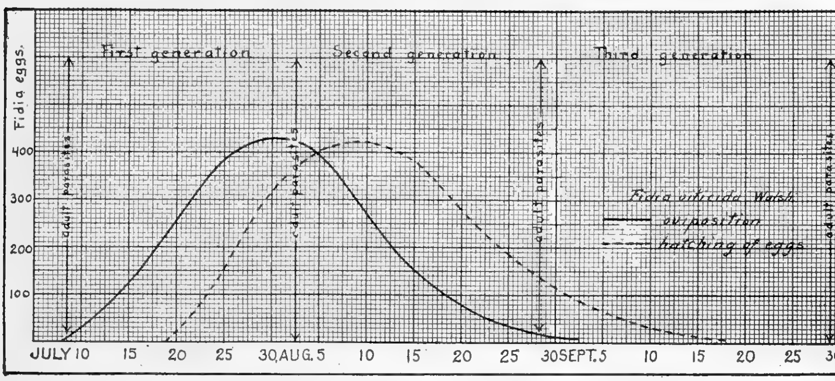


FIG. 25.—Diagram showing the relation between the three generations of the Fidiobia parasite and the relative occurrence of eggs of the grape root-worm at North East, Pa., during 1909. (Original.)

grape root-worm in Ohio, reported in 1896 that the decrease in numbers of the beetle was largely due to this and other parasites. Though the data on hand for North East, Pa., for the years 1907, 1908, and 1909 are not sufficient to show any increase in occurrence, it is our impression, from extensive observations, that the insect is becoming more and more numerous.

A DIPTEROUS PARASITE.

Along with *Fidiobia flavipes* there occurs another grape root-worm egg parasite (fig. 26), which is at present only known in the larval stage. It is supposed to be a dipterous insect, in view of the resemblance of the larva to dipterous forms. It was first observed by the senior author and Mr. P. R. Jones, of the Bureau of Entomology, who in 1907, at North East, Pa., collected several parasitized egg clusters.

During the summer of 1909 parasitized eggs were in evidence in the field from July 20 to August 30, and were found locally quite abundant, though less so than *Fidiobia flavipes*. Professor Webster informed the junior writer that he had found a similar parasite in Ohio in 1896. Table XXIII shows the relative occurrence of para-

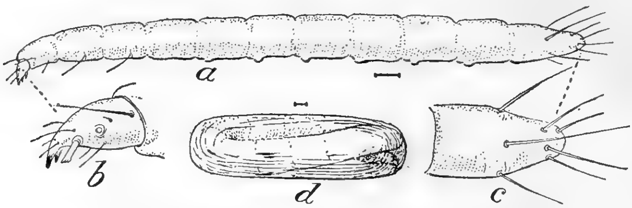


FIG. 26.—Larva of an undetermined insect parasite of the eggs of the grape root-worm. (Original.)

sitized eggs as observed at various stages in different localities during 1909 at North East, Pa.

TABLE XXIII.—*Percentage of eggs of the grape root-worm parasitized by a dipterous insect, as observed in vineyards in the vicinity of North East, Pa., 1909.*

Date.	Vineyard.	Per cent.
July 20	Davidson	1
July 22	Porter	1
July 24	Mosher	3
Aug. 4	Algren	7
Aug. 12	do	22
Aug. 19	do	12
Aug. 26	do	14

It will be noted that there is an increase in the occurrence of the parasite toward the end of the season, as was observed with Fidiobia.

Root-worm eggs parasitized by this insect are in their early stages opaque-white in color. Later the eggshell becomes semitransparent and iridescent. The larva of the parasite when full-grown is almost twice the length of the host and lies folded within the egg. The whitish larvæ are very active on emerging from the hosts. They were found to penetrate several inches in the soil in glass jars. Though the larva is quite common, all attempts to rear the insect to obtain the adult or fly have so far proved fruitless.

DOUBLE PARASITISM.

August 30, 1909, a cluster of 115 root-worm eggs was collected, which were infested by the dipterous parasite. The egg along the border of the cluster, unlike the rest, a few days later assumed a pink color, but at the same time showed the iridescence characteristic of this parasite. Dipterous larvæ emerged September 3 from the eggs of the central portion of the cluster. From the eggs along the border of the cluster a hymenopterous fly (*Lathromeris fidiæ* Ashm.) (fig. 27)

emerged. The host had been confined indoors during the winter, thus bringing out the hymenopterous parasite on February 2. It is probable that the root-worm eggs were first parasitized by the dipterous insect and that later the eggs along the margin of the cluster were parasitized a second time by *Lathromeris fidiæ*. The dipterous and the hymenopterous insects are undoubtedly both primary parasites.[a]

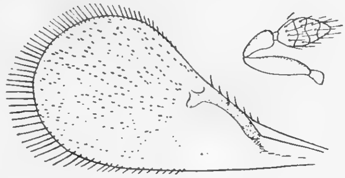


FIG. 27.—*Lathromeris fidiæ*, an egg-parasite of the grape root-worm: Antenna and fore wing. Very greatly enlarged. (Original.)

VINEYARD CONDITIONS IN THE LAKE ERIE VALLEY.

Before entering upon a discussion of methods of control undertaken against the grape root-worm during this investigation it may be well to consider some of the changes which have occurred in vineyard conditions throughout the Lake Erie valley since the advent of this pest.

In 1900, when the grape root-worm first appeared in injurious numbers in the Lake Erie valley, the grape industry was just emerging from a period of depression which had caused, for several years previous, an almost complete cessation in planting of new vineyards. The period of low prices had resulted in indifferent care, amounting in some cases to positive neglect, thus creating a condition very favorable to the increase of this pest. Furthermore, the fact that practically all vineyards had been for several years in bearing and had a well established root system permitted the insect to become thoroughly disseminated through them before the unsuspecting owners were aware of its presence in numbers sufficient to affect the vigor of their vines. The tendency of most vineyardists at that time was to pull out declining vineyards rather than to go to the expense of fighting insect foes. Thus it happened that a combination of circumstances conspired to favor a general spread of the insect without creating widespread alarm.

With the steady rise in the value of grapes since 1900, however, this condition has been reversed. Thousands of acres of new vineyards have been planted, and the more progressive vineyardists are commencing to appreciate fully what an enormous amount of injury has been done to their old vineyards, and are greatly alarmed at the rapidity with which many young vineyards are falling a prey to this pest.

The maximum crop yield for the Lake Erie grape belt occurred in 1900, and amounted to 8,000 carloads of fruit. At that time there

[a] The authors are indebted to Mr. A. A. Girault, of the office of the state entomologist of Illinois, for the determination of the above-named parasites.

were about 30,000 acres of vineyards in bearing. Since 1900 fully 10,000 acres of bearing vines have been added to this area, yet the yield for 1908 was only a little more than one-half that of 1900.

The figures given below are taken from the Chautauqua Grape Belt, a newspaper which is largely devoted to the grape interests of that region and every year publishes carefully gathered statistics on grape production.

Grape production from 1900 to 1909.

Yield for—	Carloads.
1900	8,000
1901	6,669
1902	5,062
1903	2,954
1904	7,479
1905	5,365
1906	5,465
1907	5,186
1908	4,232
1909	7,561

These figures denote a steady decline in crop yield traceable to a variety of causes, namely, depletion of soil, lack of proper cultivation, adverse weather conditions, and lack of proper fertilization. There are thousands of acres of vineyard throughout the belt that have borne many crops and have never received a pound of fertilizer. It is doubtful, however, if all of these factors combined could of themselves have resulted in such unfavorable vineyard conditions as have been brought about by the ravages of the grape root-worm. We make this statement advisedly after several seasons of careful study of the habits and depredations of the pest.

The table presents certain points of interest. Thus, in 1903 there was an especially light crop of 2,954 carloads followed by a large crop in 1904. About the same conditions prevailed during the respective years 1908 and 1909. It should be borne in mind that a considerable percentage of the phenomenal increase during the years 1904 and 1909 must be credited to the greater vigor of the plants following the light crops of the preceding years and to extremely favorable weather conditions.

In the early history of this infestation, as previously mentioned, practically all of the vineyards of the belt contained old vines with a well-established root system able to withstand for several seasons even a heavy infestation of the larvæ before a marked decrease in yield was noticeable. With the extensive planting of new vineyards since the thorough dissemination of this pest its swift and deadly work has become more apparent. Numerous instances have come to our notice where young vineyards bearing the second or third season's crop have been so severely injured that hundreds of vines died

outright in a single season, while the rest were so weakened that they had to be cut back so severely that in the following season they were unable to produce more than from 15 to 25 per cent of a normal crop. Persons not thoroughly familiar with the habits of the pest have frequently charged this death and weakened condition to a variety of causes, such as winter killing, deep plowing, overbearing of young vines, etc. In practically every case of this kind coming under our observation we have found overwhelming evidence of injury wrought upon the roots by the larvæ of this pest. There is no doubt that the overbearing of young vines which possess a limited root system and then become subject to a heavy infestation of grape root-worm larvæ will serve to greatly weaken the vine, and that severe winter weather following this heavy infestation of larvæ, and consequent weakening of the vine, will accelerate the death of the vine during the winter. Yet these are but secondary evils to which the vines, primarily weakened by injury from the insect during the growing season, finally succumb. This is also true of drought conditions occurring in August and September. During the drought which occurred in these months in 1906 numerous cases came under our notice where young vines bearing a heavy crop of fruit and having made a heavy growth of vine early in the season were so badly injured by larvæ hatching from eggs deposited in July that they were unable to mature the fruit, which actually shriveled on the vine by the last week in August. Other injured vines which carried through their crop died during the following winter. It is the rapid decline in yield of large numbers of vines in young vineyards throughout the whole grape belt and the steady though less perceptible shrinkage in yield of the other vineyards that make it impossible for the increased planting of recent years to more than hold its own with the crop production of the period previous to the general infestation of vineyards by this pest, and it will require the greatest care and watchfulness on the part of those planting new vineyards to carry their young bearing vines through that critical period when they are producing their first two or three crops and at the same time establishing a root system sufficient to continue the production of successive profitable crops.

REMEDIAL MEASURES FOR THE CONTROL OF THE GRAPE ROOT-WORM.

EVOLUTION OF PREVENTIVE MEASURES.

Although the occurrence of this insect in numbers sufficient to cause great damage to the foliage of grapevines was brought to the attention of Walsh in 1866, no remedial measures were suggested by him. The first record of an attempt to control the pest was made

in 1870 by C. V. Riley, who relates an instance where a vineyardist, having observed that the beetles have the habit of falling from the foliage to the ground when the vines are jarred and that they have a tendency to "play possum," and also that they were readily devoured by his chickens, was able to destroy many of them in his vineyard by having a boy drive his flock of chickens through the vineyard while he shook the beetle-infested vines in front of them.

In 1872 Kridelbaugh suggested handpicking of the beetles from the vines and also the use of an arsenical spray.

Not until 1895, however, when Professor Webster made his investigation of the pest in Ohio, were methods for its control seriously considered. During his investigation Professor Webster conducted experiments with salt, kainit, tobacco, kerosene emulsion, and carbon bisulphid against the larvæ in the soil, all of which appear to have given indifferent results. The carbon bisulphid, although partially effective, was likely to injure the roots of the vines and was also too expensive to be practicable. He also used kerosene emulsion against the adults, both on the foliage and after they had fallen to the ground. Pyrethrum in solution was used in the same manner, but with very indifferent results. Arsenical sprays were applied to the foliage in an attempt to poison the beetles, using London purple and Paris green, 4 ounces to 50 gallons of water, and arsenate of lead, 1 pound to 150 gallons of water. Although there was evidence that some beetles were destroyed by the use of these arsenicals, the results were far from conclusive. Later experiments in Ohio with arsenicals against the pest gave more encouraging results, yet the practice of spraying as a method of control never became general. Therefore in 1900, when the insect appeared in destructive numbers in the vineyards of Chautauqua County, N. Y., it was again the subject of experimentation by both the late Prof. M. V. Slingerland, of Cornell University Agricultural Experiment Station, and by Prof. E. P. Felt, of the New York State Museum to determine effective methods of control.

During the early part of the investigation it was shown that early in June the larvæ come near the surface of the soil to make the pupal cells in which they transform to beetles, and that thorough stirring of the first 3 or 4 inches of the soil, especially beneath the trellis, will expose and destroy a large number of the pupæ. On account of the somewhat unsatisfactory and inconclusive results obtained with arsenical sprays in former years in Ohio, Doctor Felt gave considerable attention to the perfecting of a device for collecting the beetles by jarring them into troughlike receptacles containing kerosene oil which could be operated either by hand or by horsepower where large areas of vineyard have to be treated. That large numbers of the beetles can be captured and destroyed by this method is demon-

strated in Doctor Felt's reports of his experiments published by the New York State Museum. (See Bibliography, p. 93.)

Experiments with arsenical sprays against the pest during the early part of the New York investigations, although giving more encouraging results than those obtained in Ohio, were not so conclusive as could have been desired. By persistent experiment with improved spraying apparatus and increased strength of arsenicals, and thorough and heavy applications where desirable, Professor Slingerland was able toward the end of his investigations to secure results with poison sprays which showed that in the hands of the thorough vineyardist very effective results could be obtained.

Unfortunately these field experiments with arsenicals were not conducted for a number of consecutive seasons on the same blocks of vineyards. This makes it impossible to determine the cumulative

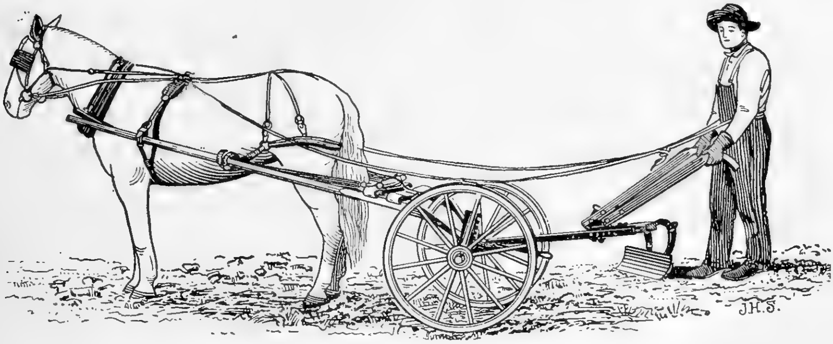


FIG. 28.—Horse hoe used in removing the soil from beneath the trellis in vineyards. (Original.)

benefits of the treatments in preventing infestation on the sprayed portion as compared with the injury wrought by the insect on the untreated portion of the vineyard.

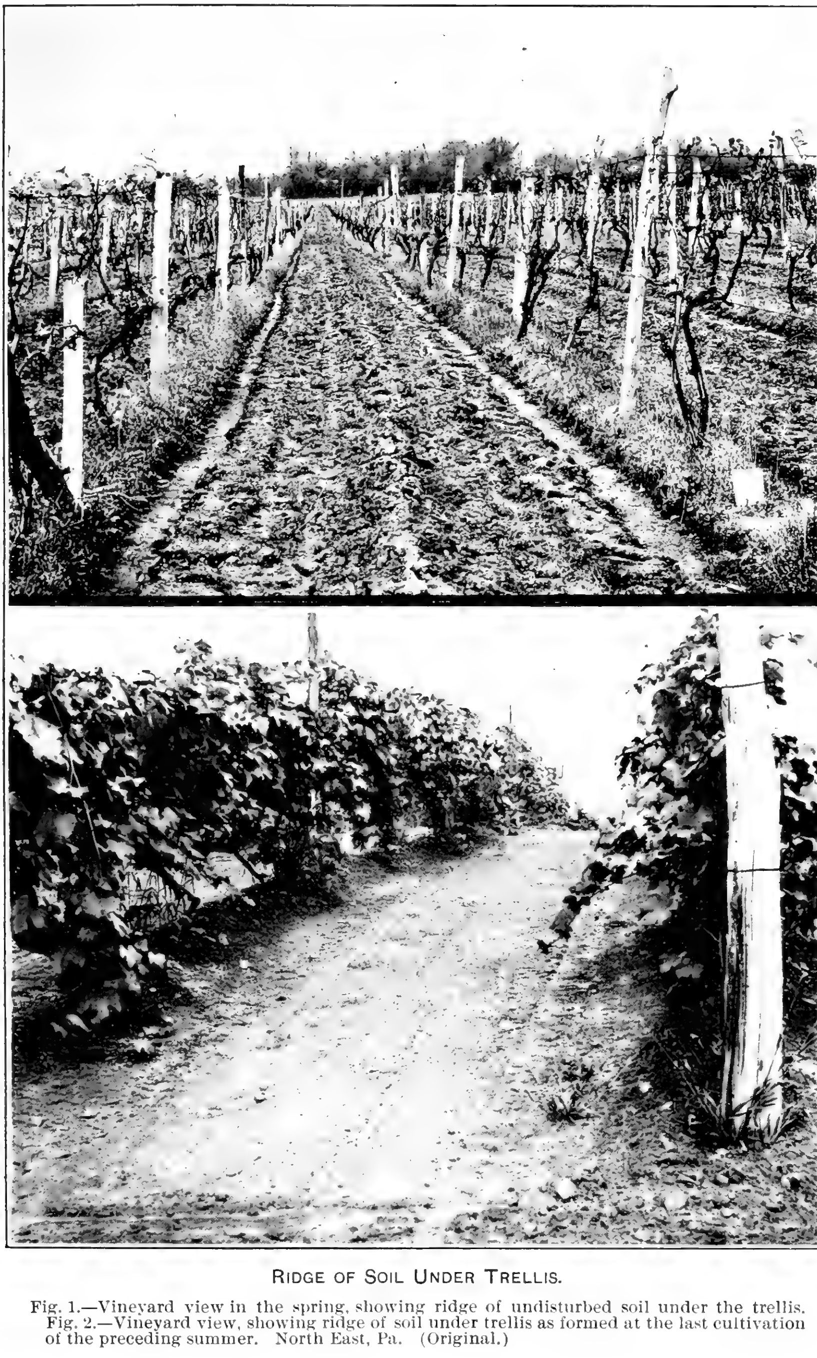
CULTURAL METHODS FOR THE DESTRUCTION OF PUPÆ.

Prior to the appearance of the grape root-worm in destructive numbers in the Lake Erie grape belt about the first cultural operation of the season performed by vineyardists was to remove the soil from beneath the trellis with a horse hoe (fig. 28) to a depth of 3 or 4 inches. This operation removed all of this layer of soil beneath the trellis with the exception of a few inches directly around the base of the vine which was removed later with a hand hoe. Almost immediately following these operations a furrow was thrown back under the trellis with a 1-horse plow, and the remaining space between the rows of grapes was stirred with a gang-plow and followed by several cultivations during the season. With the discovery that the grape root-worm larva has the habit of coming near the surface of

the soil to make its pupal cell, this plan of cultivation has been somewhat modified. In order to encourage the larva to come still higher above the roots of the vine to pupate than it would have done under ordinary cultural methods it has become customary to throw up a ridge of soil beneath the trellis at the last cultivation of the preceding summer (see Pl. V, fig. 2). Observations have shown that it is highly desirable that this ridge be formed under the trellis late in the summer rather than in the early spring, since in the former case the soil becomes of a uniform compactness by the time the larvæ are ready to migrate nearer to the surface to pupate; whereas, if the ridge is formed in the spring a layer of trash and leaves accumulating under the trellis during the winter is sandwiched in this ridge, and in no case in our examinations have we found pupal cells above this layer of trash. In the operation of horse hoeing this spring-formed ridge away from the vines it frequently happens that only the layer above the trash is thrown away, hence the pupæ, which are all beneath the trash, are undisturbed.

Undoubtedly this modification in the plan of early cultivation of vineyards is an important aid in the destruction of this pest at a time when it is in its most critical stage of development. Instances have come directly under our observation where we have seen great numbers of the pupæ exposed to the air and sunlight or become the immediate prey of birds and predaceous insects. The operation is probably of greater value in sandy and loose gravelly soils than in stiff clay soils, for in the former the earthen cells fall apart quite readily with the disturbance of the soil, leaving the pupæ exposed; whereas in the clay the soil is more likely to turn over in lumps, leaving many of the cells intact. In addition to this, in soils of a sandy or gravelly nature the loose earth around the vines may be removed by the horse hoe to a much greater depth and more pupæ disturbed than in the case of stiff clay soils, where it frequently happens that the operation of horse hoeing amounts to little more than a scraping of the weeds from the surface of the ground, especially if the season be a dry one. In fact, the drying out of the soil is the chief drawback to placing reliance on this operation as a means of controlling this pest.

It not infrequently happens that a dry period may occur along the Lake Erie Valley during the month of June which renders it difficult to make horse hoeing as thorough and as timely as it should be to derive the greatest benefit from this operation in the destruction of the pupæ. In the summer of 1907 when the development of the pupæ was unusually late the operation of horse hoeing was postponed by some vineyardists until the last of June and early July in order to perform it at a time when the maximum number of the insects were in the pupal stage, and considerable complaint was forthcoming



RIDGE OF SOIL UNDER TRELLIS.

Fig. 1.—Vineyard view in the spring, showing ridge of undisturbed soil under the trellis. Fig. 2.—Vineyard view, showing ridge of soil under trellis as formed at the last cultivation of the preceding summer. North East, Pa. (Original.)

from large vineyardists concerning the undesirability of suspending horse hoeing until so late a date. In 1907 we saw many hundreds of acres of vineyard in the condition shown in Plate V, figure 1, in which cultivation had been suspended to await the development of the pupæ. Under normal conditions this cultivation would have been performed several weeks earlier, and since early and thorough tillage is essential to good vineyard management, it is not well to place entire reliance on this operation to control the pest. Nevertheless it is an operation that should be utilized whenever soil and moisture conditions will permit, and these are most favorable in sandy and gravelly soils and in seasons of moderate rainfall during the month of June. The most beneficial results from this operation are obtained by horse hoeing as deeply as possible without scraping the roots, followed by thorough and deep hand hoeing around the crown of the vine, at which point by far the greater number of pupæ are to be found.

During this investigation we have never felt warranted in placing entire dependence upon this method of destroying pupæ to control this pest, but have regarded it as a valuable supplementary aid obtained by a slight modification of general vineyard practice at no additional expense to the vineyardist and that other means must be employed to destroy the beetles developing from pupæ which escape destruction by this method. Since we were unable to find vineyardists with heavily infested vines who were willing to allow us to conduct an experiment covering several acres for several consecutive seasons, depending entirely on the destruction of pupæ by cultivation, it is impossible to present definite data as to the exact value of this treatment.

EFFECT OF POISON SPRAYS ON THE BEETLE IN THE FIELD.

The use of poison sprays against the beetles of the grape root-worm after they have emerged from the soil and commenced to feed upon the foliage of grapevines has been recommended by many entomologists since the insect has become of economic importance as a vineyard pest.

Extensive experiments with arsenicals were made by Webster in Ohio in 1895, and also by Slingerland and Felt in Chautauqua County, N. Y., in a number of field experiments conducted during the seasons from 1902 to 1906.

Although in many of these experiments the results obtained indicated a considerable degree of benefit from the use of arsenical poisons, especially in those made by Slingerland from 1904 to 1906, there has always been an element of doubt as to the value of arsenical sprays applied to the vines as a direct and rapid killing agent of the beetles. The inference has been drawn by some experimenters that

the beneficial effects of poison sprays are due rather to a distaste on the part of the beetles for poisoned foliage, and their consequent abandonment of sprayed foliage and migration to unsprayed areas, than to the direct killing effect of the poison. This view is supported to some extent by cage experiments which showed that in many cases when confined in cages the beetles fed but slightly upon sprayed foliage and the death rate was not as rapid as might be wished. In addition to this, beetles thus confined with poisoned vines have in feeding indicated a preference for unsprayed areas, all of which left reasonable cause for doubt as to the direct efficiency of arsenicals as a killing agent.

During our investigation of this pest, covering the seasons of 1907, 1908, and 1909, we have observed this tendency of the beetles to feed more freely upon the unpoisoned than upon poisoned foliage, both in the open vineyard and in cages, yet we have no direct evidence of wholesale migration of the beetles from sprayed areas.

CAGE EXPERIMENTS WITH POISON SPRAYS AGAINST THE BEETLES.

On July 13, 1907, 100 beetles recently emerged from the soil were divided into two lots of 50 each and placed in cages; one cage contained sprayed foliage collected from a vineyard recently sprayed, the other unsprayed foliage. The beetles in the cage containing the unsprayed foliage fed freely upon the leaves soon after they were placed in the cage, whereas those placed in the cage containing the sprayed foliage did but little feeding during the first 3 days. During the next 3 days there was evidence of an increased amount of feeding. At the end of the 6 days, 25 of the beetles feeding on the sprayed foliage had died as against 6 dead beetles out of the 50 feeding on the unsprayed foliage. At this date (July 19) the experiment terminated on account of the withering of the sprayed foliage, and the impossibility of obtaining additional recently sprayed foliage.

Another cage experiment to observe the feeding of beetles upon poisoned and unpoisoned foliage was undertaken during the summer of 1909. This experiment was made upon young grapevines growing in large flower pots and covered with a wire screen (see fig. 22). Thus the freshness of foliage was assured throughout the experiment and the limited area of the plant permitted close observation of what took place. Three plants growing in pots were used in this experiment. The plants in two of the pots were sprayed very thoroughly, care being taken to cover the entire upper surface of all of the leaves with a poisoned spray, which consisted of Bordeaux mixture with 3 pounds arsenate of lead to 50 gallons of the mixture, the proportions used in field experiments. The plant in the third pot was unsprayed. An

additional object of this experiment was to observe the readiness with which beetles that had just emerged from the soil and had not had a previous opportunity of feeding on unsprayed foliage would feed on poisoned foliage as compared with beetles which were taken from vineyards and which had fed to some extent upon unsprayed vines. Accordingly 30 beetles, on emerging July 8, from soil inclosed with wire screens, were placed on a sprayed plant in pot I. Thirty more beetles collected in a vineyard, June 30, and fed on unsprayed leaves until July 8, were placed (July 8) in pot II, also containing a sprayed plant. At the same date 15 beetles which had just emerged were placed on an unsprayed plant in pot III.

Table XXIV shows the death rate of the beetles in these three cages.

TABLE XXIV.—*Experiments with poison sprays against grape root-worm beetles feeding on vines in confinement at North East, Pa., in 1909.*

Pot I.		Pot II.		Pot III.	
30 beetles emerged from soil July 8, and at once removed to sprayed vine.		30 beetles taken on vines in the field June 30 and placed on sprayed vine July 8.		15 beetles emerged from soil July 8, and removed at once to unsprayed vine.	
Number of dead beetles.	Date.	Number of dead beetles.	Date.	Number of dead beetles.	Date.
16	July 9	3	July 9	1	July 15
12	July 10	10	July 10	1	July 27
2	July 11	13	July 11	1	July 29
		2	July 12	1	July 31
		1	July 13	7	Aug. 14
		1	July 17	3	Aug. 15
				1	Aug. 28
30	....	30	....	15	Total.

It was observed that the beetles just emerged from the soil and which had been placed in pot I without having had an opportunity to come in contact with unsprayed foliage fed as readily and indiscriminately on the poisoned leaves as did those placed on the unsprayed plant in pot III. The beetles placed on the other sprayed plant in pot II, which had had 8 or 10 days of feeding on unsprayed leaves, fed less upon the sprayed foliage, especially for the first 24 hours. A glance at the table will show that 50 per cent of the beetles in pot I died in 24 hours as against 10 per cent in pot II. On the fourth day all beetles in pot I had died and also 85 per cent of those in pot II, whereas it was not until the eighth day of the experiment that the first dead beetle was found in pot III, and 73 per cent of the beetles remained alive on this plant for more than a month.

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FIELD EXPERIMENTS WITH POISON SPRAYS AGAINST THE BEETLES.

The most striking evidence of the value of a poison spray as a direct killing agent of the beetles, however, was obtained by us in a field experiment conducted at North East, Pa., June 30, 1909. At this date our attention was called by Mr. Frank Pierce to the presence of large numbers of grape root-worm beetles feeding upon a block of several acres of vines planted that spring. These vines had been planted on land from which the vines of the greater portion of an unproductive vineyard had been removed early the same spring. The owner, not being aware at the time that these vines had been

FIG. 29.—Young grapevine, unsprayed, showing extensive feeding by beetles of the grape root-worm. North East, Pa., 1909. (Compare with fig. 30.) (Original.)

rendered unproductive by infestation by the grape root-worm, decided to replant the area immediately with young vines. After removing the old vines the ground was plowed and planted to the young vines and the space between these vines was sown to peas. Thus the soil was left uncultivated during the period between early May, when the peas were sown, and July 1. Consequently the root-worm larvæ which had infested the roots of the old vines were permitted to perform their transformations undisturbed. On June 28, when Mr. Pierce harvested the peas growing between the rows of grapevines, he observed some grape root-worm beetles feeding upon

foliage of the young vines. By June 30, when our attention was called to the infestation, the leaves of many of the plants were badly riddled by the beetles (see fig. 29). At our suggestion Mr. Pierce sprayed part of these young vines quite thoroughly, using Bordeaux mixture and 3 pounds arsenate of lead to 50 gallons of the mixture. This application was made with a hand spray pump mounted on a grape wagon, and the spray was directed at the plants by a man following behind the wagon and carrying an extension rod with two nozzles at the end and connected with the spray pump by a long lead of hose. In this way 4 rows of vines could be treated from the wagon. The vines were sprayed on the afternoon of June 30. It should also be stated that the portion of the old vineyard not removed in the spring and adjoining the young vines was treated at the same time. On the afternoon of July 1 an examination was made of the effect of the treatment of the previous day. Only a few beetles were found on the young vines as compared with the large numbers present previous to the application of the poison spray. Close examination of the soil beneath the vines disclosed the presence of a large number of dead beetles. Eighteen dead beetles were found beneath one vine, and under a number of others from 3 to 10 dead beetles were found. In addition to this we observed that a small brown ant was very actively removing evidence of the direct effect of the poison by tearing to pieces the dead beetles and often dragging away the whole body of the beetle. Wing-covers, heads, and legs of several beetles were to be seen beneath a single vine, and in several cases ants were observed to attack the beetles before they were quite dead.

A visit was also made to the old trellised vines adjoining them, anticipating evidence of a wholesale migration of beetles from the young vines to the denser foliage of the old vines. Such, however, was not the case; although there was evidence of considerable feeding at an earlier date, few beetles were now observed on the vines. Several dead beetles were found beneath these old vines, and fragments of beetles and their wing-covers were also observed. A few days later a second application of Bordeaux mixture and arsenate of lead was made on these vines to take care of later emerging beetles. On a visit to these young vines July 10 not more than 4 live beetles were observed, although more than an hour was spent in the block, and not a single dead beetle was found on the ground beneath the vines, although fragments of their bodies were in evidence. If this timely application of a poison spray had not been made, the young vines would have been seriously injured by the feeding of the beetles; for it not infrequently happens that the beetles, where they are numerous and the foliage limited, as in this case, riddle the foliage and tear it into shreds until it has the appearance of being singed by fire.

In view of the results described above, there can be no doubt as to the value of a poison as a direct and effective killing agent of the beetles in the open field. It is quite possible, moreover, that the rapid removal of dead bodies by ants and other agencies and the close search required to find them on account of the fact that their color is the same as that of the soil, and also by the fact that they were distributed over a large area on the foliage of full-grown vines, have resulted in the failure of other workers to find a sufficient number of dead bodies of beetles in sprayed vineyards to warrant them in feeling that this method of control is as effective as might be desired.

COMPARATIVE EFFECTIVENESS OF ARSENATE OF LEAD AND ARSENITE OF LIME.

In our field work with arsenical sprays, planned for a period of two or three seasons, arsenate of lead was the insecticide used throughout the experiments. Since, however, many vineyardists were using arsenite of lime when this investigation commenced, it was deemed advisable to make a test of its efficiency as an insecticide against the grape root-worm beetle as compared with arsenate of lead.

In the summer of 1907 a test of these two insecticides was made in two vineyards in different parts of the township of North East. One vineyard of about 8 acres belonging to Mr. W. S. Wheeler was divided into three plats. Two plats of about 3 acres each were sprayed, one with Bordeaux mixture and arsenate of lead and the other with Bordeaux mixture and arsenite of lime. The third plat of about 2 acres running through the middle of the block was left unsprayed. Two spray applications were made on these plats at the same dates, July 9 and July 27, with a gasoline-engine power sprayer (Pl. X, fig. 2). The spray was applied at a pressure of about 100 pounds, and about 100 gallons of the liquid were used per acre. The formula used on the plat sprayed with arsenite of lime was, copper sulphate, 5 pounds; lime, 6 pounds; resin-fishoil soap, 2 pounds, and 1 quart arsenite of lime made according to Kedzie's formula (containing 4 ounces of white arsenic) to 50 gallons of water. The resin-fishoil soap was added to increase the mixture's property of adhering to the foliage. The formula used on the plat sprayed with arsenate of lead was, copper sulphate, 5 pounds; lime, 5 pounds; arsenate of lead, 3 pounds; and water, 50 gallons. The effect of these treatments in preventing egg deposition is shown by a count of the egg clusters on 25 vines in each of the three plats. It should be stated in addition that at the time of making the count of egg deposition there was evidence of a great deal more feeding by beetles on the foliage on the plat treated with arsenite of lime than upon the

foliage of the plat sprayed with arsenate of lead. (For results, see Table XXV.)

TABLE XXV.—*Relative value of arsenite of lime and arsenate of lead as insecticides, as shown by egg depositions at North East, Pa., 1907.*

VINEYARD OF W. S. WHEELER.

Date of application.	Formula.	Size of clusters. Large.	Medium.	Small.	Total clusters.	Estimated number of eggs.	Number of vines.	Number of canes.	Eggs per vine.	Eggs per cane.	Date examined.
1907.	Unsprayed	37	102	151	290	6,420	25	50	256.8	128.4	Aug.14
July 8	5-6-2-50+1 quart Kedzie	27	98	132	257	5,610	25	65	224.4	86.3	Do.
July 27	5-5-3-50	3	14	47	64	1,040	25	51	41.6	20.39	Do.

VINEYARD OF W. E. GRAY.

Date of application.	Formula.	Large.	Medium.	Small.	Total clusters.	Estimated number of eggs.	Number of vines.	Number of canes.	Eggs per vine.	Eggs per cane.	Date examined.
	Unsprayed	28	119	139	286	6,360	25	75	254.4	84.8	Aug. 17
July 6 July 25	Prepared Bordeaux: 1 qt. arsenite lime, 2 qts. fishoil soap, 50 gals. water	21	107	155	283	5,810	25	63	232.4	92.22	Do.
July 6 July 25	Prepared Bordeaux: 3 lbs. arsenate of lead, 50 gals. water	11	49	78	136	2,800	25	58	112.0	48.27	Do.

The vines on all these plats were quite thrifty and were carrying a heavy foliage.

The second experiment for comparing the value of these two poisons against the grape root-worm beetle was made on a 12-acre vineyard belonging to Mr. W. E. Gray, North East, Pa. The vineyard was divided into three plats, 5 acres on the east side, 2 acres through the middle of the block, and 5 acres on the west side. In this experiment a commercial brand of prepared Bordeaux mixture was used. The poison ingredients of the spray, however, were the same as in the experiments on the vineyard of Mr. Wheeler. The plat on the east side of the vineyard was sprayed with a mixture of 2 gallons prepared Bordeaux mixture, 1 quart of arsenite of lime, Kedzie formula, 2 quarts of fishoil soap, and 50 gallons of water. The plat on the east side of the vineyard was sprayed with a mixture of 2 gallons of prepared Bordeaux mixture, 3 pounds of arsenate of lead, and 50 gallons of water. The 2 acres through the middle of the vineyard were left unsprayed. As in all of our other spray experiments, the foliage in the untreated plat showed much more feeding by the beetles at the time of taking the records of egg deposition. A greater amount of feeding by the beetles was also apparent on the foliage treated with arsenite of lime than upon that treated with arsenate of lead. The results of these experiments are set forth in

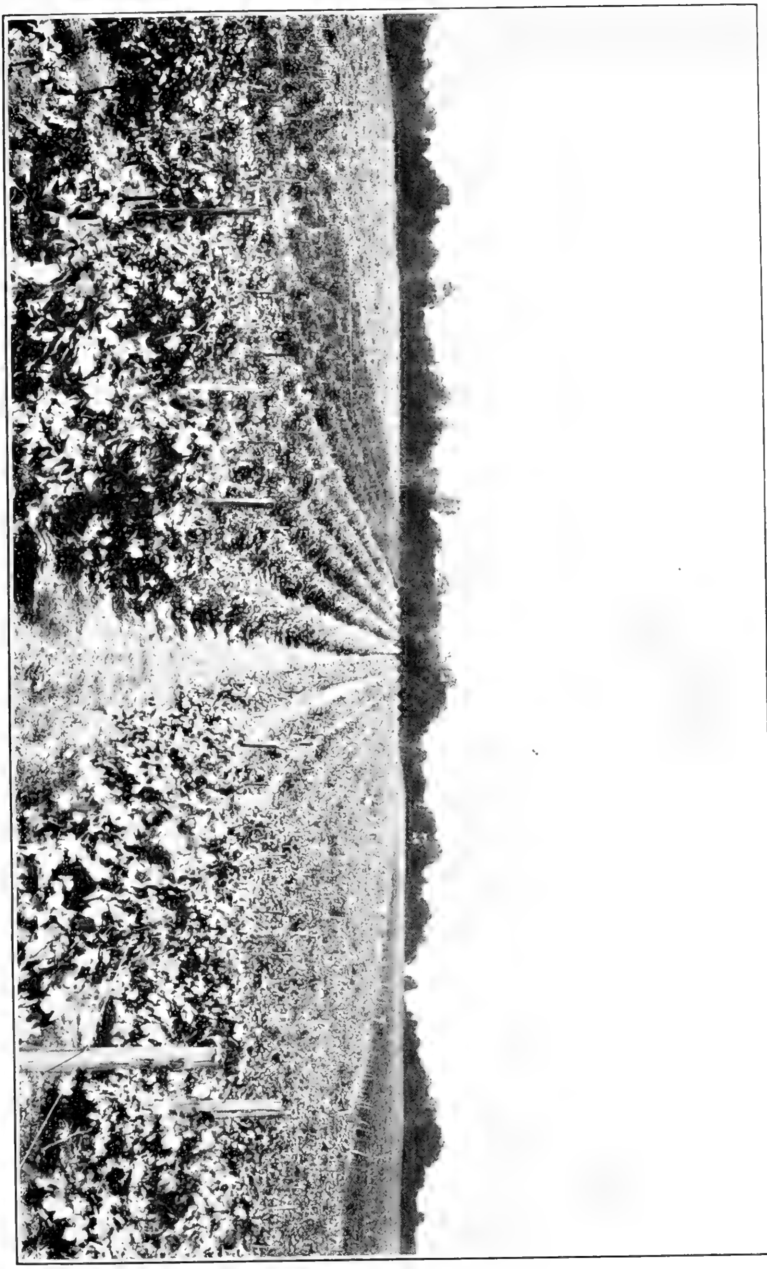
Table XXV and indicate a much greater efficiency from the arsenate of lead application than from the application of arsenite of lime.

Vineyardists throughout Erie County have practically abandoned the use of arsenite of lime as a poison spray against the grape root-worm beetle, and arsenate of lead is now used almost exclusively.

RESULTS OF VINEYARD EXPERIMENTS WITH POISON SPRAYS.

The field experiments of this investigation were carried on during the three consecutive seasons of 1907, 1908, and 1909, and in view of results obtained by spraying by the senior author during his single season of cooperative work with the late Prof. M. V. Slingerland the remedial measures tried out were almost entirely along the line of spray applications, it being his belief that the most effective results could be obtained by this method of combat. Some of the principal points upon which information was desired were the effect of poison sprays in ridding the vines of the grape root-worm beetles, the effect of this application in preventing egg deposition by beetles, the relative effect of this treatment on vines of different ages and different stages of infestation, the determination of the immediate seasonal benefit to the vines by prevention of egg deposition, and the cumulative benefit both in vigor of vines and crop yield obtained by following up a line of treatment for several consecutive seasons.

A brief survey of vineyard conditions in the townships of North East, Pa., during the late summer of 1906 enabled us to make a selection of vineyard areas in the various stages of infestation and decline best suited to the working out of these problems. A block of vineyard owned by Mr. Roscoe Davidson, of North East, was selected for the experiment to determine the effect of poison applications. The conditions existing in this vineyard were well suited to the plan of experiment. The area was about 12 acres, thus making it possible to secure results of commercial value. The vineyard (Pl. VI) is situated on a northern slope and is divided into four blocks or sections. The soil is of a loose gravelly texture. The lower northern section consists of young Concord vines about 7 years planted, the two sections immediately above are made up of vines about 20 years planted and are referred to as old Concords, and the south section consists of a block of 7-year-old Niagara vines referred to in these experiments as young Niagaras. At the time the experiment was undertaken the whole block showed a uniformly heavy infestation of larvæ on the roots of the vines. With the exception of the section of young Concords, however, the vines had not yet reached the stage of serious decline and were still producing fairly profitable crops. With the young Concords the case was different. Our attention had been called to these vines late in the summer of 1906 at the time when the fruit was commencing to color.



GENERAL VIEW OF MR. ROSCOE DAVIDSON'S VINEYARD AT NORTH EAST, PA., WHERE SPRAYING EXPERIMENTS AGAINST THE GRAPE ROOT-WORM WERE CONDUCTED DURING 1907, 1908, AND 1909. THE DARK AREA IS THE UNSPRAYED PLAT. (ORIGINAL.)

So serious was the injury of the larvæ to the roots at this date that the large crop of fruit which some of these vines were carrying was actually shriveling up and dropping to the ground. By the following spring many of these vines had either died outright or were in a very weakened condition. Plate IV, figure 2, gives an example of the manner in which the fibers had been removed from the roots of many of these young vines by the larvæ of the root-worm, and shows the limited growth of new canes as a result of the infestation which rendered the vine incapable of producing a crop of fruit during the coming season. Thus the variety of conditions existing in this vineyard was such as to enable us to work out several features of the problem on the same block, namely, the effect of a poison-spray application on vines of different varieties, of different ages, and in different stages of injury, all growing side by side under practically the same conditions. All of the vineyard was subjected to the same treatment in regard to cultivating, fertilizing, and spraying, with the exception of six rows running through the center of the block (Pl. VI) which cut through all four of the sections mentioned above. These six rows were reserved as a check and from these the spraying alone was withheld.

Below are given all of the data relating to the experiment conducted on this vineyard during the seasons of 1907, 1908, and 1909, together with the results obtained.

As the time for the emergence of the beetles from the soil drew near daily visits were made to this vineyard during the latter end of June and early July, 1907. On July 15 an occasional beetle was found feeding on foliage near the ground. All preparations had been made for spraying as soon as the first beetles appeared, and the first application was made at this date. The sprayer used was a gasoline-engine power outfit constructed especially for vineyard work (Pl. X, fig. 2). The regular Bordeaux formula, 5–5–50, was used, and to this 3 pounds of arsenate of lead were added, this latter ingredient being the active poison agent of the spray. A pressure of about 100 pounds was maintained throughout the application, and about 100 gallons of spray mixture were applied per acre. Fixed nozzles were used of the eddy chamber type.

On July 23 a second application was made, the same formula being used and the same pressure maintained.

During the season of 1908–9 the same spray formula, machinery, and nozzle arrangement were used and the same pressure maintained. The only varying factor was the dates of application, which varied each season with the date of emergence of the beetles. To facilitate comparison, the dates of application, effect of spray on egg deposition, prevalence of larvæ at roots, and crop yield as compared with the unsprayed check are tabulated for the three seasons. (Tables XXVI, XXVII, and XXVIII.)

TABLE XXVI.—*Effect of poison spray against the grape root-worm as shown by relative occurrence of eggs in sprayed and unsprayed plats in Davidson vineyard for 1907, 1908, and 1909, North East, Pa.*

Date of application.	When examined.	Number of egg clusters found.				Estimated number of eggs.	Number of vines.	Number of canes.	Average number of eggs.	
		Large.	Medium.	Small.	Total.				Per vine.	Per cane.
CHECK (UNSPRAYED) PLAT—YOUNG CONCORD VINES.										
	Aug. 2, 1907	92	163	246	501	11,950	25	55	478	217.2
	July 13, 1908	31	109	190	330	6,720	25	29	268.8	231.7
	July 19, 1909	41	41	74	156	4,020	25	35	160.8	114.8
SPRAYED PLAT—YOUNG CONCORD VINES. Formula: 5 lbs. blue vitriol (copper sulphate), 5 lbs. lime, 3 lbs. arsenate of lead, 50 gallons water.										
July 15, July 23	Aug. 2, 1907	7	10	22	39	870	25	66	34.8	13.8
June 22, June 30	July 13, 1908	0	5	16	21	310	25	41	12.4	7.5
July 2, July 14	July 19, 1909	1	7	12	20	380	25	47	15.2	8.8
CHECK (UNSPRAYED) PLAT—OLD CONCORD VINES.										
	Aug. 2, 1907	52	136	213	401	8,810	25	69	352.4	127.6
	July 13, 1908	47	139	146	332	7,980	25	71	319.2	112.3
	July 19, 1909	35	57	91	183	4,370	25	68	174.8	64.2
SPRAYED PLAT—OLD CONCORD VINES. Formula same as above (5-5-3-50).										
July 15, July 23	Aug. 2, 1907	4	13	13	30	720	25	72	28.8	10.0
June 22, June 30	July 13, 1908	2	13	10	25	590	25	64	23.6	9.2
July 2, July 14	July 19, 1909	0	7	7	14	280	25	81	11.2	3.4
CHECK (UNSPRAYED) PLAT—YOUNG NIAGARA VINES.										
	Aug. 6, 1907	32	74	77	183	4,590	25	49	183.6	93.6
	July 15, 1908	11	18	31	60	1,400	25	34	56.0	41.4
	July 19, 1909	3	9	15	27	570	25	51	9.6	4.7
SPRAYED PLAT—YOUNG NIAGARA VINES. Formula same as above (5-5-3-50).										
July 15, July 23	Aug. 6, 1907	0	2	1	3	70	25	35	2.8	2.0
June 22, June 30	July 15, 1908	0	1	0	1	30	25	36	1.2	.69
July 2, July 14	July 19, 1909	1	4	7	12	240	25	51	9.6	4.7

TABLE XXVII.—*Effect of poison spray against the grape root-worm as shown by occurrence of larvæ at roots of vines in sprayed and unsprayed plats in Davidson vineyard in 1907, 1908, and 1909, at North East, Pa.*

Date of examination.	Number of vines.	Variety and age of vines.	Number of larvæ. Unsprayed plat.	Number of larvæ. Sprayed plat.
DIGGINGS MADE IN SUMMER OF 1907.				
September 5, 1907	1	Young Concord	92	6
Do	1	Old Concord	91	1
Do	1	Young Niagara	6	0
DIGGINGS MADE IN SUMMER OF 1908.				
August 26, 1908	10	Young Concord	214	40
August 25, 1908	5	Old Concord	86	4
Do	5	Young Niagara	58	5
DIGGINGS MADE IN SUMMER OF 1909.				
September 8-9, 1909	5	Young Concord	39	0
September 10-15, 1909	5	Old Concord	13	0
September 11-15, 1909	5	Young Niagara	17	0

TABLE XXVIII.—*Davidson vineyard. Effect of spray applications on the crop yield for the seasons 1908 and 1909 at North East, Pa.*

Year.	Variety and age of vines.	Treatment.	Plat area.	Plat yield.	Value per basket.	Value per acre.	Spray benefit per acre.
FOR SEASON OF 1908.							
			Acre.	*Lb.baskets*	*Cents.*		
1908	Young Concord	Sprayed	½	101.8	13	$26.26	$5.20
1908	do	Unsprayed	½	81.8	13	21.06	
1908	Old Concord	Sprayed	¾	502.0	13	86.97	8.06
1908	do	Unsprayed	¾	455.0	13	78.91	
1908	Young Niagara	Sprayed	⅓	231.4	9	62.37	21.87
1908	do	Unsprayed	⅓	150.4	9	40.50	
FOR SEASON OF 1909.							
1909	Young Concord	Sprayed	½	435.8	11	$95.70	$47.96
1909	do	Unsprayed	½	217.0	11	47.74	
1909	Old Concord	Sprayed	¾	1,039.0	11	152.35	39.70
1909	do	Unsprayed	¾	836.0	11	112.65	
1909	Young Niagara	Sprayed	⅓	158.2	28	132.72	61.32
1909	do	Unsprayed	⅓	85.0	28	71.40	

The effect of the spray on egg deposition was obtained by stripping all of the loose bark from 25 consecutive vines in the sprayed portion and also in the check rows, making an actual count of the number of egg clusters deposited on an equal number of consecutive vines in the sprayed and unsprayed plats. This has proved to be one of the best ways to determine the immediate direct effect of spray applications. These examinations were made at a time, determined by careful

observation, when the maximum number of eggs had been deposited, and before but few larvæ had hatched from the earliest deposited eggs.

All of the bark was carefully stripped from the vine and a count made of the egg clusters found. The number of eggs in these clusters may vary from 3 or 4 to 75 or even 100. Since it was impossible to make an actual count of the individual eggs, the clusters were classified, as the count was made during the examination of the vines, as *large* when they contained approximately 50 eggs or more, *medium* when they contained about 30 eggs, and *small* when they contained about 10 eggs. In this manner we obtained the estimated number of eggs per vine given in the Table XXVI dealing with egg deposition. A simple enumeration of the number of egg clusters deposited per vine regardless of the number of eggs which they contained would have given but an inadequate idea of the total number of larvæ which might infest the roots of these vines. The number of canes per vine is also given to indicate the size of the vine, since the limit of the area upon which the beetles could deposit eggs would have some influence on the number of clusters deposited.

The prevalence of larvæ at the roots of vines in sprayed and unsprayed plats was determined by making careful diggings at the roots of a given number of vines in both the sprayed and the unsprayed plats (Table XXVII). During these diggings the difference in the number of root fibers thrown out by vines in the sprayed and unsprayed plats was very noticeable. On May 13, 1908, after the vineyard had received the protection of one season's treatment with poison spray the root systems of several vines were examined in the block of young Concords. It was found that the roots of many of the vines in the unsprayed plat were almost entirely devoid of new root fibers, and that the large roots were badly channeled and pitted by the feeding of the larvæ of the grape root-worm, whereas the roots of vines examined in the sprayed portion of this vineyard showed that they had thrown out large masses of new fibrous roots during the growing season as a result of the protection the spraying had afforded them in the prevention of the deposition of eggs by the beetles. Plate IV, figure 1, will illustrate this luxuriant growth of new root fibers on roots of sprayed treated vines, practically all of which were produced during the growing season of 1907, as compared with the lack of them on the unsprayed vines (Pl. IV, fig. 2). These illustrations also indicate the recuperative power of badly injured grape vines when protection from the larvæ is afforded; for in the spring of 1907, previous to the protection of the vines by the poison spray, the roots of the vines in the sprayed plat were as devoid of root fibers as were those in the unsprayed plat, as was shown by diggings made in the spring of 1907.

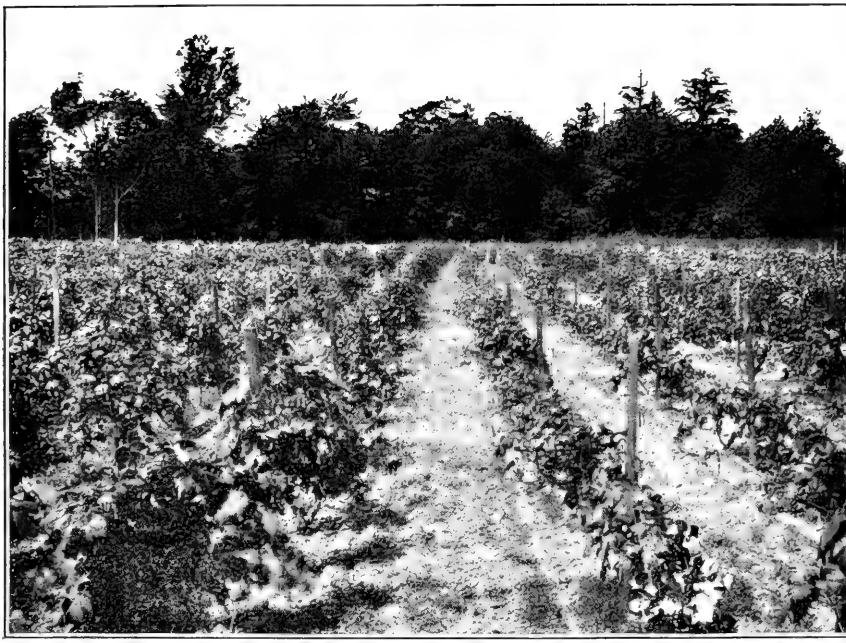


Fig. 1.—Retarded growth of vines in the unsprayed plat. (Original.)

Fig. 2.—Vigorous growth of vines in the sprayed plat. (Original.)

VIEWS OF EXPERIMENTAL PLATS IN MR. ROSCOE DAVIDSON'S VINEYARD AT NORTH EAST, PA.

In addition to the above-described methods of comparing the effect of the treatment of this vineyard with a poison spray, an accurate count of the number of baskets of grapes picked from equal areas in the sprayed and unsprayed plats was made and their cash value for each season recorded. This data, covering the seasons 1907, 1908, and 1909, is presented in Table XXVIII.

Plate VII, figure 1, shows the light growth of the vines in the unsprayed plat as compared with Plate VII, figure 2, showing the heavy growth in the sprayed plat after three years' treatment.

RESULTS OF VINEYARD RENOVATION EXPERIMENTS.

At the time this investigation was commenced the feeling was quite common among vineyardists of North East, Pa., that it would be useless to attempt to restore to their former productivity some of the vineyards very badly injured by the root-worm, and that it would be cheaper to tear out these old vines and replant the ground to new vines. In view of the fact that our survey had shown that many young vineyards just coming into bearing were also declining very rapidly under attacks of the pest, and that a run-down condition of old vines was very common throughout the entire grape belt, it was deemed desirable to investigate as to what could be done in the way of renovating a badly run-down vineyard.

RENOVATION EXPERIMENT ON AN OLD VINEYARD.

During the fall of 1906 our attention had been called to the condition of 10 acres of old vineyard which in previous years had possessed the reputation of being very productive but had suddenly shown a rapid decrease in yield and also in growth of vine. The yield of this vineyard, which in 1905 was 6,597.5 pounds of fruit per acre, declined in 1906 to 1,697 pounds per acre, showing a decrease of 4,900.5 pounds and barely covering operating expenses. When visited by us in the fall of 1906 the foliage of these vines was found to be riddled by the beetles of the grape root-worm, the cane growth was stunted, and many vines simply threw out tufts of puny shoots near the lower wire of the trellis. The roots were almost devoid of fibers and badly scarred by the feeding of grape root-worm larvæ, and the fruit hung in scraggy clusters of undersized berries—in short, this vineyard had all the appearance of being in the last stages of production as a result of grape root-worm injury. In the spring of 1907 it was decided to undertake an experiment in this vineyard to determine if by ridding the vines of this pest, the vineyard could be restored to its former condition of profitable production. At this point it should be stated that the vineyard had received in previous years only indifferent cultivation and practically no fertilizing or spraying. The importance

of these operations was recognized at the outset of the experiment and arrangements were made to give the vines thorough cultivation and liberal fertilizing in addition to thorough spraying with a poison and a fungicide; in fact, to treat the vineyard according to the most approved methods of vineyard management.

That spring when the vineyard was pruned many of the badly weakened vines were cut back to the ground and others to the lower wire of the trellis. Even on the most vigorous vines, not more than one to three fruit-bearing canes were left, it being thought desirable to concentrate the remaining energies of the weakened vines and force the vegetative growth rather than attempt to produce fruit of an inferior quality such as was borne by the vines during the season of 1906. In order that some light might be thrown on the effect of different kinds and amounts of fertilizer used in restoring these injured vines it was decided to divide the vineyard into seven plats of one acre each and the following kinds and amounts of fertilizer were applied:

Plat I. Barnyard manure, 7 wagon loads.

Plat II. Complete high grade commercial fertilizer, 1,000 pounds.

Plat III. Complete high grade commercial fertilizer, 1,000 pounds plus 100 pounds sodium nitrate.

Plat IV. Sodium nitrate, 400 pounds.

Plat V. High grade commercial fertilizer, 1,000 pounds.

Plat VI. High grade commercial fertilizer, 500 pounds.

Plat VII. No fertilizer; no spraying.

The brand of fertilizer used in 1907–8 analyzed available phosphoric acid, 11.28 per cent; potash, 5.89 per cent; nitrogen, 3.41 per cent. In 1909 a brand of fertilizer was used analyzing phosphoric acid, 8 per cent; potash, 8 per cent; nitrogen, 5 per cent. The plats commenced on the west side of the vineyard and ran eastward. Plats I, V, VI, and VII included seven rows measuring approximately one acre in area. Plats II, III, and IV contained 14 rows each, but all the data here given are reduced to a 7-row or 1-acre basis for convenience in comparison. The ground on which this vineyard is planted is quite level and is of a stony loam on the west side grading to an almost stoneless clay on the east side where it has been somewhat enriched by wash from a slight elevation lying immediately south, which doubtless is responsible for the greater productivity of plats 5, 6, and 7, at the beginning of the experiment.

The barnyard manure was spread broadcast over the rows of Plat I during the month of April. The commercial fertilizer was distributed on the other plats in two equal applications, the first being made May 21, when active growth of the vines commenced. The second application was made June 18, about one month later.

All of the fertilizer was applied with a broadcast fertilizer distributor and immediately followed by a spring-tooth cultivator.

The ground was plowed early in May and received three thorough cultivations during the summer. It should be observed at this point that this is by no means an attempt to solve the problem of vineyard fertilization, which belongs to the province of the horticulturist, and that the results obtained on these plats are presented without comment upon this feature of the experiment, leaving the reader to draw his own conclusions.

With the appearance of the first beetles all of the plats except the check plat received a thorough spraying with Bordeaux mixture and arsenate of lead, using the following formula: Copper sulphate, 4 pounds; quicklime, 4 pounds; arsenate of lead, 3 pounds. A second spraying with the same ingredients was made ten days to two weeks later. (See exact dates on Table XXIX, showing egg deposition.)

TABLE XXIX.—*Effect of poison spray against the grape root-worm as shown by relative occurrence of eggs on sprayed and unsprayed plats of the Porter vineyard during 1907, 1908, and 1909, at North East, Pa.*

UNSPRAYED PLAT.

Year	When examined.	Number of egg clusters found.				Estimated number of eggs.	Number of vines.	Number of canes.	Average number of eggs.		Date of spray application.
		Large.	Medium.	Small.	Total.				Per vine.	Per cane.	
1907..	Aug. 12, 1907	97	150	238	485	11,730	25	76	469.2	154.37	....
1908..	July 22, 1908	45	91	78	214	5,760	25	76	230.4	78.9	....
1909..	July 21, 1909	37	56	94	187	4,470	25	97	178.8	46.08	....

SPRAYED PLAT.

Formula: 4 lbs. blue vitriol (copper sulphate), 4 lbs. lime, 3 lbs. arsenate of lead, 50 gallons water.

Year	When examined.	Large.	Medium.	Small.	Total.	Estimated number of eggs.	Number of vines.	Number of canes.	Per vine.	Per cane.	Date of spray application.
1907..	Aug. 13, 1907	1	21	34	56	1,440	25	56	57.6	25.7	July 13 July 22
1908..	July 22, 1908	0	10	4	14	340	25	58	13.6	5.8	June 24 July 2
1909..	July 21, 1909	3	8	7	18	460	25	117	18.4	3.9	July 5 July 16

The spray applications were made with a gasoline-engine spraying outfit specially mounted for vineyard work (Pl. X, fig. 2) having an arrangement of fixed nozzles, three on each side, the two lower of which throw the spray on the side of the vines as the machine passes through the rows. The upper nozzle reaches out over the top of the row throwing the spray downward so that it covers the new growth at the top of the trellis. This downward direction of the spray to cover the new growth at the top of the trellis is highly desirable since the beetles exhibit a tendency to feed more freely on this new growth, especially after the lower leaves have been coated with a poison spray. A pressure of from 100 to 125 pounds was maintained throughout

the operation, using about 100 gallons of spray liquid per acre. With this spraying outfit it is possible to cover from 8 to 10 acres of vineyard per day.

METHODS OF OBTAINING AND RECORDING RESULTS.

As in the preceding field experiment, the results of the spray application were determined by counting the number of egg clusters deposited on the vines by the grape root-worm beetles at a time when the maximum number of eggs were to be found upon the vines. All of the bark was removed from 25 consecutive vines in the unsprayed plat and also in the adjoining sprayed plat. The results of these examinations are given in Table XXIX for the three seasons 1907, 1908, and 1909. Table XXX indicates the effect on the larvæ of spraying as shown by the number of larvæ found at the roots of the vines by carefully removing the soil from the base of the vine for a distance of 3 or 4 feet from the trunk of the vine and to a depth of a foot or 16 inches, going several inches below the second whorl of roots.

TABLE XXX.—*Effect of poison spray against the grape root-worm as shown by relative occurrence of larvæ at roots of vines in sprayed and unsprayed plats of Porter vineyard, at North East, Pa., in 1907, 1908, and 1909.*

Date of examination.	Number of vines.	Variety and age of vines.	Number of larvæ.	
			Unsprayed plat.	Sprayed plat.
April and May	40	20-year Concord	76	
September 25, 1907	5	....do	92	
May 27-28, 1908	10	....do	100	21
June 19, 1909	12	....do	67	7
September 25, 1909	5	....do	115	19

When the crop was ready to harvest, the final effect of the season's treatment was obtained for each plat. Table XXXI indicates the plat number, area, fertilizer applied, number of crates or baskets of grapes, net weight of fruit, value per pound or basket, cash value per acre, cost of spraying and fertilizing, and value of crop less cost of treatment.

The data in Table XXXI, giving the results of the treatment from 1907 to 1909, inclusive, show a great increase in crop yield of this vineyard as a result of thorough spraying and heavy fertilization. This experiment proves conclusively that if energetic measures are taken with vineyards rendered practically unprofitable as a result of grape root-worm injury they may be made to yield very profitable crops.

TABLE XXXI.—*Crop yield of plats in renovation experiments for 1907, 1908, and 1909, at North East, Pa.*

FOR SEASON OF 1907.

Plat number.	Plat area.	Kind of fertilizer used.	Number of 8-pound baskets per acre.	Net weight of fruit in pounds per acre.	Average value of fruit per 8-pound basket for 1907, 1908, 1909.	Value of fruit per acre.	Cost of two spraying applications per acre.	Cost of fertilizer and application per acre.	Value of fruit less cost of spraying and fertilizing per acre.
	Acre.				*Cents.*				
I	1	Barnyard manure	129	968	12½	$16.11	$4.00	$22.00	—$9.89
II	1	Commercial fertilizer, 1,000 pounds.	198	1,485	12½	24.75	4.00	18.50	2.25
III	1	Commercial fertilizer, 1,000 pounds; sodium nitrate, 100 pounds.	211	1,590	12½	26.37	4.00	21.00	1.37
IV	1	Sodium nitrate, 400 pounds	194	1,460	12½	24.25	4.00	10.50	9.75
V	1	Commercial fertilizer, 1,000 pounds.	308	2,310	12½	38.50	4.00	18.50	16.00
VI	1	Commercial fertilizer, 500 pounds.	255	1,917	12½	31.87	4.00	9.50	18.37
VII	1	No fertilizer; no spraying	263	1,975	12½	32.87	....	....	32.87

FOR SEASON OF 1908.

Plat number.	Plat area.	Kind of fertilizer used.	Number of 8-pound baskets per acre.	Net weight of fruit in pounds per acre.	Average value of fruit per 8-pound basket for 1907, 1908, 1909.	Value of fruit per acre.	Cost of two spraying applications per acre.	Cost of fertilizer and application per acre.	Value of fruit less cost of spraying and fertilizing per acre.
	Acre.				*Cents.*				
I	1	Barnyard manure	427	2,606	12½	$53.37	$4.00	$22.00	$27.37
II	1	Commercial fertilizer, 1,000 pounds.	482	2,921	12½	60.25	4.00	18.50	37.75
III	1	Commercial fertilizer, 1,000 pounds; sodium nitrate, 100 pounds.	590	3,542	12½	73.75	4.00	21.00	48.75
IV	1	Sodium nitrate, 400 pounds	649	3,912	12½	81.12	4.00	10.50	66.62
V	1	Commercial fertilizer, 1,000 pounds.	681	4,153	12½	85.12	4.00	18.50	62.62
VI	1	Commercial fertilizer, 500 pounds.	630	4,022	12½	78.75	4.00	9.50	65.25
VII	1	No fertilizer; no spraying	535	3,369	12½	66.87	....	....	66.86

FOR SEASON OF 1909.

Plat number.	Plat area.	Kind of fertilizer used.	Number of 8-pound baskets per acre.	Net weight of fruit in pounds per acre.	Average value of fruit per 8-pound basket for 1907, 1908, 1909.	Value of fruit per acre.	Cost of two spraying applications per acre.	Cost of fertilizer and application per acre.	Value of fruit less cost of spraying and fertilizing per acre.
	Acre.				*Cents.*				
I	1	Barnyard manure	1,188	9,049	12½	$148.50	$4.00	$22.00	$122.50
II	1	Commercial fertilizer, 1,000 pounds.	1,282	9,898	12½	160.26	4.00	18.50	137.76
III	1	Commercial fertilizer, 1,000 pounds; sodium nitrate, 100 pounds.	1,184	9,146	12½	148.00	4.00	21.00	123.00
IV	1	Sodium nitrate, 400 pounds	1,037	8,372	12½	129.62	4.00	10.50	115.12
V	1	Commercial fertilizer, 1,000 pounds.	1,171	9,090	12½	146.37	4.00	18.50	123.87
VI	1	Commercial fertilizer, 500 pounds.	1,260	9,580	12½	157.50	4.00	9.50	144.00
VII	1	No fertilizer; no spraying	855	6,412	12½	106.87	....	....	106.87

In examining the yields for the various plats it will be observed that in the first year of the experiment plats I, II, III, and IV fell considerably below the unsprayed and unfertilized plat. This condition is due in a great measure to the fact that vines in plats V, VI, and VII were in a somewhat more thrifty condition at the outset of the experiment. The soil in these plats grades to a clay loam and has been enriched somewhat by the wash from an elevation immediately south of them. While the untreated plat shows great improvement in yield simply as a result of thorough cultivation, yet the annual increase in yield on this plat was much less than that upon the treated plats in the same soil.

In addition to this increase in crop yield there was noted a great improvement in the quality of the fruit both in size of berries and of clusters. Plate IX, figure 2, gives a comparison of the size and compactness of fruit on a vine in the sprayed portion as compared with fruit on a vine in the unsprayed portion shown in Plate IX, figure 1.

It was also found that the fruit in the sprayed plats remained firm and that there was practically no loss from shelling of the berries, whereas the fruit and stems in the unsprayed plat were badly mildewed and there was a great deal of shelling of berries. This benefit is derived from the fungicidal effect of the Bordeaux mixture. This increase in crop yield has also been accompanied by a marked improvement in the vigor of the vines throughout this vineyard. Practically all of the vines are now in a condition to produce a full crop of fruit, and there is no reason why this vineyard should not continue to produce as profitable crops as it did previous to its infestation, provided it is subjected to treatment similar to that which it has received during this investigation.

Plate VIII affords a comparison of the growth of vine at the beginning and at the end of the experiment, the upper figure showing the vineyard at the beginning of the experiment, and the lower figure after three years' treatment.

RENOVATION EXPERIMENT ON A YOUNG VINEYARD.

About the year 1900 there was a heavy planting of new vineyards throughout the Lake Erie grape belt. Scarcely had these young vines come into bearing when the owners noticed a rapid decline both in their crop yield and in vigor of vines. Close observation indicated that this decline was due largely to injury by the grape root-worm, and that the decline of these young vines was even more rapid than in the case of older, well-established vines. In many vineyards it was found that young vines had been killed outright in a single season.

VIEWS OF THE PORTER EXPERIMENTAL VINEYARD, SHOWING COMPARATIVE GROWTH OF THE VINES IN 1907 AT THE BEGINNING OF THE EXPERIMENT (UPPER FIGURE), AND IN 1909 AT THE END OF THE EXPERIMENT (LOWER FIGURE), NORTH EAST, PA. (ORIGINAL.)

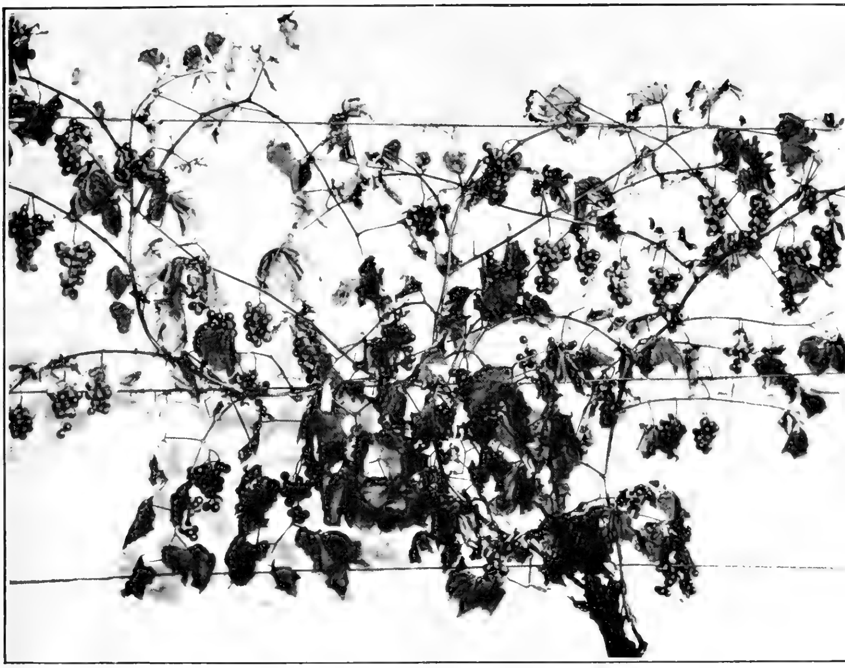


Fig. 1.—Average condition of berries in the untreated plat, North East, Pa., 1909. (Original.)

Fig. 2.—Average condition of berries in the treated plats, North East, Pa., 1909. (Original.)

CONDITION OF FRUIT ON VINES IN PLATS OF THE PORTER EXPERIMENTAL VINEYARD.

During the summer of 1907 our attention was called to the condition of a young vineyard near North East, Pa., belonging to Mr. H. E. Mosher, which for the first three years of bearing had maintained a very thrifty condition. The soil of this vineyard had been well cultivated and heavily fertilized with barnyard manure, yet in spite of this favorable treatment the crop yield in 1907 decreased to an alarming extent, amounting only to about one-eighth of the value of the yield for the previous season.

This vineyard is about 5 acres in extent. The crop value in 1904, first year bearing, was $127.51; in 1905 it was $410.77; in 1906 it was $435.72, but in 1907 it was only $55.92

There is every reason to believe that the grape root-worm was directly responsible for the sudden decline of these vines, for when the roots of many of the vines, which were practically dead, were examined by us they were found to be entirely devoid of fibrous roots, and the whiplike larger roots and the crowns of the vines were badly furrowed and scarred as a result of feeding by the full-grown larvæ (Pl. III). From one section of this vineyard, about 2½ acres in area, containing 1,584 vines, 563 dead vines were removed in the spring of 1908. In addition to this, about 50 per cent of the remaining vines were cut back either to the ground or to the lower wire of the trellis, thus greatly limiting their fruit production for the coming season. So discouraged was the owner with the condition of this vineyard that he was at the point of pulling out all of the vines and replanting it anew. At our request, however, he permitted us to plan a renovation experiment on this section to determine if the vines could be restored to a thrifty condition and again produce profitable crops. This experiment was commenced in the spring of 1908. The remaining vines were severely cut back, as mentioned above, and new vines planted in the place of those which had been removed. The vines were heavily fertilized with a high-grade fertilizer. In this case, owing to the limited root area, as a result of the feeding by the larvæ, it was deemed desirable to sprinkle the fertilizer by hand about the base of the vines instead of scattering it broadcast over the whole area between the rows. Twelve rows received an application of 400 pounds of nitrate of soda and 24 rows received an application of high-grade commercial fertilizer at the rate of 2,000 pounds per acre. This fertilizer was distributed in two applications; the first on May 21, when active growth was well started, and the second about a month later.

With the appearance of the first beetles, June 23, 1908, the vines were sprayed thoroughly with Bordeaux mixture and arsenate of lead, using 4 pounds of copper sulphate, 4 pounds of stone lime, and 3

pounds of arsenate of lead to 50 gallons of water. On July 2, 1908, a second application was made, using the same formula as for the first application. The spray was applied with a traction sprayer at a pressure of about 100 pounds, and about 100 gallons of fluid were used per acre, covering the vines quite thoroughly with a fine spray. The whole 5 acres were included in each of these two spray applications. As a result of this treatment most of the vines made quite a vigorous growth of wood, which gave a good supply of bearing canes for next season. Owing to the severity with which these vines were cut back in the spring, the cash value of the crop from the 5 acres was $31.02.

The treatment given this section of vineyard in 1908 was duplicated during the summer of 1909. The same amount of fertilizer was applied, and two applications of spray were made, the first application June 29, the second July 8. As a result of the second season's treatment the vines have taken on a healthy appearance and made a vigorous growth of new canes. The number of grape root-worm beetles has been reduced to a minimum, as shown by the small amount of feeding on the foliage and by the number of egg clusters deposited. An examination made on July 24 showed but nine egg clusters on 25 sprayed vines as against 73 egg clusters on the same number of unsprayed vines. Diggings made in search of larvæ showed a similar condition. Only three larvæ were found about the roots of five sprayed vines as against 55 larvæ found about the roots of five untreated vines. The crop value for the season of 1909 for the 5 acres was $213.92 as against $31.02 for the season of 1908. The vineyard has made sufficient growth of vines during the season to enable the owner to put up enough bearing canes to produce a full crop for 1910.

The additional cost of the operations of spraying and fertilizing for the seasons of 1908 and 1909, over and above ordinary vineyard management, amounted to $135, itemized as follows:

Nitrate of soda, 1,000 pounds	$25.00
Complete fertilizer, 2 tons	70.00
Spray material and labor, $4 per acre	40.00

The success of this attempt to restore this 5 acres of vineyard to its former state of productivity can not be better summarized than by presenting the following figures showing net weight of fruit and the crop value for the years 1904 to 1909, inclusive:

	Pounds.	Value.
1904	11,630	$127.51
1905	23,705	410.77
1906	21,130	435.72
1907	3,195	55.92
1908	4,390	31.02
1909	19,935	213.92

The owner of this vineyard is greatly pleased with the results obtained by the treatment described above and is satisfied that a continuation of these methods will in another season restore his vineyard to its full bearing capacity of 1905. It might be added that previous to this experiment Mr. Mosher was very skeptical regarding the possibility that this pest could work such havoc in vineyards and also as to the value or necessity of a spray treatment. During this experiment, however, he has become a thorough convert, and is satisfied that the intelligent use of a poison spray has been the chief factor in the restoration of his vines.

SPRAYS.

ARSENICAL POISONS.

Arsenic in some form or other is usually the active killing agent used against insects which secure their food by chewing upon the foliage or fruit of plants, and since the grape root-worm beetles belong to the category of chewing insects the direct killing agent (or stomach poison) applied to grapevines is the arsenical poison which the spray mixture contains.

There are several forms of arsenicals used as insecticides. Those that have been most commonly used in the past are Paris green and arsenite of lime. Arsenite of lime is a common home-prepared insecticide made by boiling together, for about 20 minutes, 1 pound of white arsenic with 4 pounds of sal-soda crystals in 1 gallon of water. This is known as the Kedzie formula; and when used with water, milk of lime made by slaking 2 or 3 pounds of good stone lime must always be added to 50 gallons of the mixture; for the boiling of the sal-soda with the arsenic is simply to put all of the arsenic into solution in order that all of it may unite with the lime to form arsenite of lime. When used with Bordeaux mixture this addition of lime is not necessary.

Another arsenical poison and the one which has largely displaced both Paris green and arsenite of lime as a stomach poison for use on foliage is arsenate of lead. In properly made arsenate of lead less than 1 per cent soluble arsenic is present, whereas in Paris green and arsenite of lime a much higher percentage of arsenic may be soluble or exist in a weakly combined state, and since it is this soluble arsenic which is injurious to foliage a much higher strength of the arsenate of lead can be used without danger of injuring the foliage. In addition to having this advantage the lead base makes the arsenate of lead much more adhesive to the foliage than either Paris green or arsenite of lime. The chief element in favor of the two latter arsenicals is that they are somewhat cheaper than arsenate of lead. However, within the past few years the increased consumption of

arsenate of lead for spraying purposes and the sharper competition among manufacturers to secure the trade have been the means of considerably lowering its cost to the consumer and the matter of price should no longer be a bar to its use.

COMBINING INSECTICIDES WITH FUNGICIDES.

Since the use of a fungicidal spray for grapevines is highly desirable and frequently absolutely necessary to hold in check fungous diseases such as mildew and black-rot, and since some of the applications for these fungous diseases and the insect pest may be made at the same date, it has become customary to combine the two treatments by adding poison in the form of arsenate of lead to Bordeaux mixture, the fungicide used against the fungous diseases.

The formula recommended for this combined treatment is asfollows:

	Pounds.
Copper sulphate (blue vitriol)	5
Fresh stone lime	5
Arsenate of lead	3
Water	50

When Paris green or arsenite of lime are the arsenicals used, 4 ounces of the former, or 1 quart of the latter prepared according to Kedzie's formula, may be added to 50 gallons of Bordeaux mixture. For reasons given above the use of arsenate of lead in preference to either of these other arsenicals is strongly urged. We here include detailed directions for making Bordeaux mixture which are given by Mr. C. L. Shear, of the Bureau of Plant Industry, in Farmers' Bulletin 284, treating of fungous diseases of the grape.

PREPARATION OF BORDEAUX MIXTURE.

Failure to secure satisfactory results from the use of Bordeaux mixture is frequently due to lack of proper care and thoroughness in its preparation, or to the use of poor material. All ready-made preparations of Bordeaux mixture in the form of a paste or a dust should be avoided, as the chemical constitutents do not properly combine in these conditions. A definite chemical compound is desired, and this can only be produced in proper form and condition by carefully following the directions given below:

Stock solution.—In order to carry on the work with the greatest convenience and economy, a considerable quantity of copper sulphate and of lime should be ready for immediate use. The copper and the lime may be prepared and kept most conveniently in the following manner:

Copper sulphate solution.—Take 100 pounds of copper sulphate (bluestone), place it in a gunny sack, and suspend it in a 50-gallon barrel of water. Kerosene or whisky barrels will be found very convenient. The copper sulphate will all dissolve in from 12 to 18 hours if suspended in a loosely-woven sack, but if it is thrown loose in the bottom of the barrel it will take several days and considerable stirring to dissolve it. This

makes a solution containing 2 pounds of copper sulphate to each gallon of water. This may be kept as long as desired without deterioration, if covered so as to prevent evaporation.

Lime solution.—The various kinds of ground and prepared lime can not always be relied upon; stone lime is therefore to be preferred, and is more likely to give uniformly satisfactory results. Slake 100 pounds of stone lime in a 50-gallon barrel, adding the lime in small quantities with sufficient water and mixing thoroughly. When the lime is all slaked fill the remainder of the barrel with water. You will now have a stock preparation of lime which when thoroughly mixed will be thin enough to dip, and pour readily. Each gallon of this preparation will contain 2 pounds of stone lime. This may be kept under cover and used as needed. Where large quantities of material are being used it is desirable to have two or more barrels each of stock lime and bluestone instead of one, so that the bluestone in one barrel may be dissolving while that in the other is being used.

Mixing copper sulphate solution and lime solution.—To prepare a 100-gallon spray tank of Bordeaux mixture, take two 50-gallon barrels and fill them nearly full of water; to one barrel add 5 gallons of the bluestone stock solution, which will be equivalent to 10 pounds of bluestone. To the other barrel add 5 gallons from the barrel of the stock lime preparation, which will be equal to 10 pounds of stone lime. Mix the lime thoroughly and allow the contents of the two barrels to run together in a trough, or through hose attached at the bottom of the barrels into the tank of the sprayer.

If an insecticide is to be used, it may now be added to the mixture.

After the mixture is prepared it should be used very soon, and not be allowed in any case to stand more than a few hours before using.

The quantities mentioned in this account of the preparation of Bordeaux mixture will give 100 gallons of the 5–5–50 formula. For the other formulas, the manner of preparation is precisely the same, and the necessary changes in quantities of bluestone and lime are easily calculated.

PLANTS FOR PREPARATION OF THE SPRAY MIXTURE.

Plate X, figure 1, shows a mixing plant erected beside a creek in a vineyard, using a hydraulic ram to elevate the water to the tank, the lime being slaked and the copper sulphate dissolved in the barrels standing upon the ground. An abundant water supply which can be delivered to the sprayer tank either by pressure or by gravity greatly minimizes both the cost and labor of preparing spray mixtures and in addition saves a great deal of time at a season when the vineyardist is almost overwhelmed with the routine work of vineyard operations.

Lack of preparation for spraying operations and failure to utilize to the greatest advantage the flow of water down creeks or from springs adjoining vineyards, either by gravity or by the use of hydraulic rams, to elevated mixing stations frequently cause the vineyardist who is rushed with work either to neglect spraying entirely or to be so delayed in making the application that it is only partly effective; whereas if plans are made in advance to simplify the mixing and loading of the spray mixture, the apparent magnitude of the task is greatly lessened. The thing of prime importance is for the vineyardist to become thoroughly convinced that spraying is one of the absolutely necessary operations in successful vineyard management.

TIME OF APPLICATION OF SPRAYS.

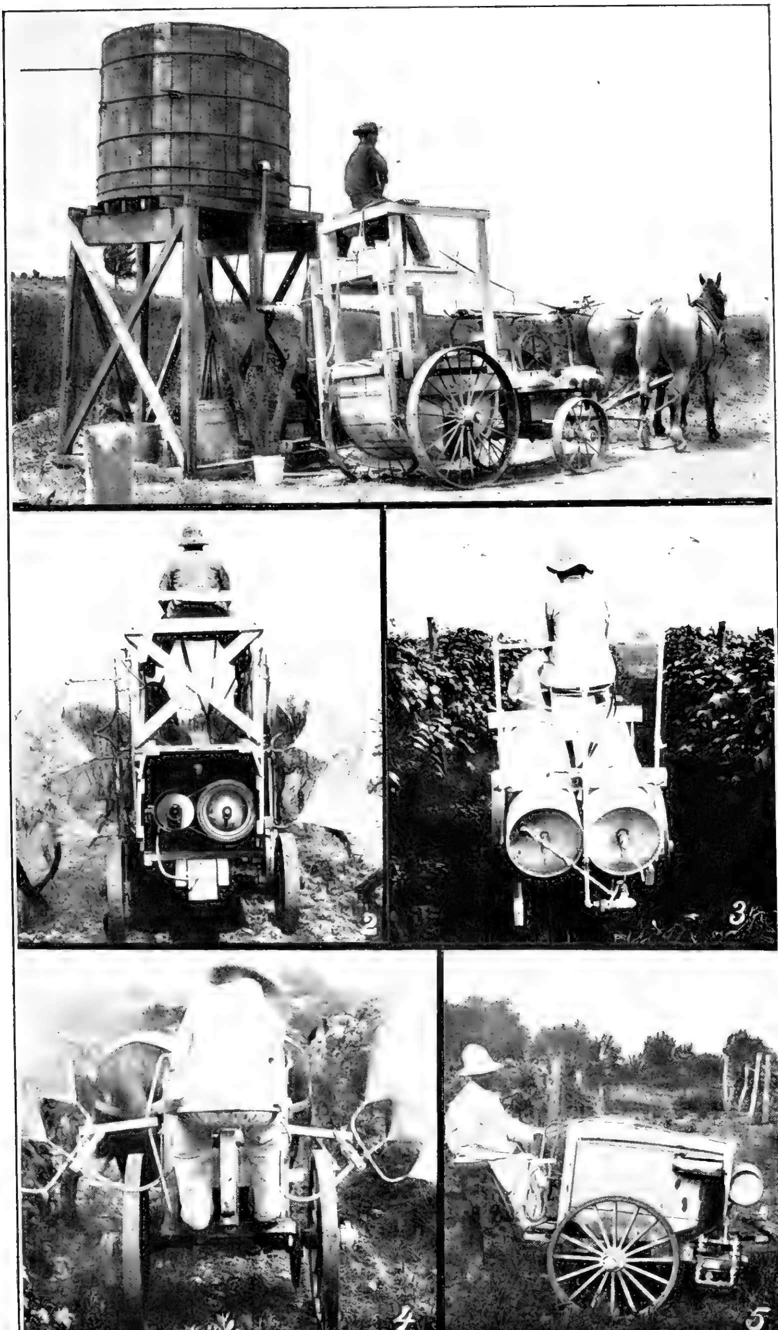
Much time and labor is actually wasted in making spray applications after beetles have done considerable feeding and deposited many of their eggs. The necessity of having all equipment and material in readiness to make the first application as soon as the first beetles appear can not be too strongly emphasized. There is no doubt that the indifferent results secured from spraying by many vineyardists is largely due to failure to make the first application as soon as the first beetles appear upon the vines.

Unfortunately no definite date can be set for the making of this first application on account of the wide range in the date of emergence of beetles from the soil from year to year, due to variations in seasonal temperature conditions, especially during the spring months. Our records show that the beetles emerged fully three weeks later in 1907 than in 1908 and spraying operations had to be planned accordingly.

Normally the first beetles may be expected to appear between the 20th and 25th of June. It should not be inferred, however, that the insect does not exist in the vineyards in serious numbers if the beetles are not in evidence at the latter date, for it happens that even experts have been led astray, as occurred in Chautauqua County, N. Y., in the spring of 1907, when experts visited the grape belt during the first week in July and, finding no beetles at this date, inferred that the pest no longer existed in very injurious numbers. Yet late in July it was found that beetles had emerged in enormous numbers in many vineyards throughout the area visited. This emphasizes the fact that only by the closest observation can the vineyardist determine the damage which this insect may inflict upon his vines and he must be fully prepared every season to combat the pest on its first appearance. A more detailed discussion of the changes in time of emergence of the beetles from year to year is given under the head of seasonal history of the insect.

NUMBER OF SPRAY APPLICATIONS.

During this investigation it has been learned that two thorough spray applications will reduce this pest to numbers which will not materially affect the health of the vine or the production of profitable crops. The second application should be made about a week or ten days after the first to cover the growth of new foliage which has developed, and also to destroy those beetles which may not have emerged from the soil at the time the first application was made. Since rearing records indicate that the maximum number of beetles emerge within the period of ten to fifteen days after the first beetles appear (see fig. 23) the small percentage of late emerging beetles will not be likely to effect very great injury. The fact that there is some



SPRAYING OUTFITS FOR VINEYARDS, IN USE AT NORTH EAST, PA.

Fig. 1.—Spray-mixing plant. Fig. 2.—Gasoline-engine sprayer in operation. Fig. 3.—Compressed-air sprayer. Figs. 4, 5.—Horsepower or geared sprayers. (Original.)

danger of staining the fruit with spray applications made much later than the middle of July is an additional reason for making the second application not later than that date.

Nearly every season since spraying grapevines with a poison has become a practice there has been more or less rumor concerning illness of persons by poisoning resulting from the eating of sprayed grapes. We have given considerable attention to looking up reports of this nature but have never been able to secure direct evidence of poisoning of persons in this manner. From our observations and

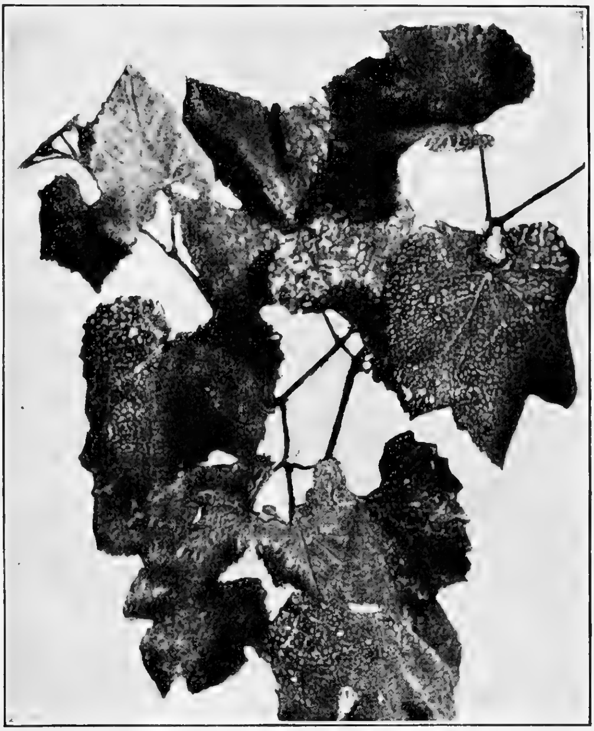


FIG. 30.—Young grapevine sprayed with arsenate of lead against the beetles of the grape root-worm. North East, Pa., 1909. (Original.)

experiments with poison sprays against the grape root-worm beetle and all other insect pests known to us at present in vineyards in the Lake Erie Valley, all applications should be made in normal seasons not later than the middle of July, and in exceptionally late seasons like that of 1907 not later than July 25. If vineyardists will endeavor to make their last poison application before that date they need have no fear of either staining their fruit or creating cause for rumor of poisoning by persons consuming the same and also may feel assured that they have made the applications at a period when they will prove most effective in the control of this pest.

PRESSURE TO BE MAINTAINED IN SPRAY APPLICATIONS.

In order that effective results may be obtained with poison sprays it is very desirable that, as nearly as possible, all of the foliage be covered with a mistlike spray. (See fig. 30.) Since in many vineyards having thrifty growing vines the foliage is quite dense during the latter part of June and early July it is necessary that this finely divided spray be thrown into the vines with considerable force. For effective work a steady pressure of not less than 100 pounds should be maintained and if this can be increased to 125 or 150 pounds still better work may be accomplished.

SPRAYING APPARATUS.

In order to cover vineyard areas of several acres in this manner it has become necessary to use power sprayers and during the past few years several types of power vineyard sprayers have come into use.

Horsepower sprayers.—Geared sprayers operated by horsepower (Pl. X, figs. 4, 5) are in general use in many vineyard sections. There are a number of sprayers of this type upon the market. With many of them, however, it is difficult to maintain a sufficiently high pressure to cover thoroughly all of the foliage without driving through the vineyard at too rapid a rate. In addition to this the nozzle arrangement is not adjusted so as to cover the foliage on the top of the trellis. A very unpleasant feature in the operation of many of these machines is that the driver is seated directly between the nozzles which are attached to the sides of the machine and consequently is drenched with the spray. It would seem however, that with a little ingenuity on the part of the manufacturers this unpleasant seating position and ineffective nozzle arrangement could be satisfactorily adjusted.

Gasoline-engine sprayers.—Many vineyardists prefer to have the power for providing pressure independent of the rate at which the machine travels through the vineyard and more directly under the control of the operator than it is with the geared sprayers. Since, however, the regulation gasoline-engine outfit used for spraying orchards is too heavy and cumbersome to use in the narrow rows of vineyards it has become necessary to mount the tank and machinery on a specially constructed shortened truck having low front wheels to admit of easy turning into the narrow vineyard rows. Plate X, figure 2, is an illustration of this type of gasoline-engine vineyard outfit and is the sprayer used for the past three seasons in making the application of poison sprays in the field experiments conducted during this investigation. An outfit of this kind has the additional advantage of being adaptable for use as an orchard outfit by simply disconnecting the fixed nozzles at the pump and connecting a lead of hose and rod when wishing to spray trees. It was for the purpose of tree spraying that the derrick or platform was erected above the tank. When used for vineyard work the derrick proved useful as an elevated seat where the driver would be clear of the spray. (See Pl. X, fig. 2.)

Compressed-air outfits.—Compressed-air outfits are a type of sprayer which find favor with a number of vineyardists and perform excellent work. The air is compressed by means of a stationary engine at the loading station and one of the cylindrical tanks is charged with air and the other filled with the spray liquid. The two tanks are connected so that the air may pass into the tank containing the liquid and force it out through the nozzles in the form of a fine spray. Since there is no machinery connected with this sprayer except at the loading station there is practically no danger of delay from machinery getting out of order while working in the field.

Carbonic-acid-gas sprayers.—Carbonic acid is employed as power in a similar manner to compressed air. It is, however, somewhat more expensive than either horsepower engines, gasoline engines, or compressed air. More or less difficulty sometimes occurs in procuring the drums of gas, which have to be obtained from large cities where this gas is manufactured. Yet there are many of these outfits in use and giving good satisfaction.

Hand pumps.—Where but limited areas of vineyard are to be treated quite effective work may be done with a pump operated by hand to treat vines, and in gardens or places where it is impossible to drive a cart a knapsack sprayer may be used. For larger areas, however, it will be found more economical to use power outfits.

The care of spraying apparatus.—For the successful operation of spray pumps it is highly desirable that the working parts be made of brass, since iron is acted upon by Bordeaux mixture. It is also important that the pump be so constructed that packing can be conveniently removed and replaced. Each time after the pump is used a few pailfuls of water should be run through the pump, hose, and nozzles to remove all of the spray mixture so that sediment in the mixture may not dry up and clog the valves and nozzles while the machine is not in use. If this precaution is taken much annoyance may be avoided when the machine is next put in operation.

Nozzle adjustment.—Practically all of the power sprayers are equipped with adjustable nozzles attached to a vertical rod firmly fastened to the sides of the tank, usually at the rear end of the machine. There are usually two or three of these nozzles set horizontally to throw the spray into the side of the vines. In addition to these horizontally directed nozzles, the uppermost nozzle should be carried out over the top of the trellis and directed downward to insure the covering of all the foliage on the top of the trellis (Pl. X, figs. 2, 3), since it is upon the new growth developing at the top of the trellis that the beetles are likely to do much feeding, especially after the lower foliage has been thoroughly covered with a spray mixture.

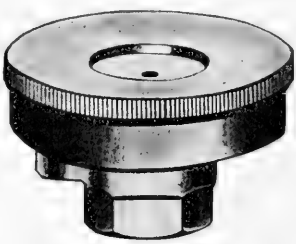


FIG. 31.—A large nozzle of the cyclone type. (Original.)

Nozzles.—Nozzles of the Vermorel type are the kind in general use for vineyard spraying and produce a fine mistlike spray which is so necessary for effective work, and for this reason they are more desirable than nozzles of the Bordeaux type, which throw a heavier, fan-shaped spray. The chief drawback with the ordinary Vermorel nozzles lies in the rapid wearing out and enlarging of the opening of the cap, resulting in a coarse spray if allowed to become too much worn. More recently larger nozzles of the Cyclone type (fig. 31) have come into general use, especially where high pressure with power machinery is used. These nozzles throw a larger cone of spray, have steel disks for caps, which can be removed when the opening becomes much worn, and possess the added advantage of not clogging so readily as the smaller Vermorel nozzles.

RECOMMENDATIONS.

DESTRUCTION OF THE ADULTS OR BEETLES.

The beetles of the grape root-worm feed upon the upper surface of the leaves of the grapevine, and may be poisoned by thoroughly spraying the foliage of the vines with an arsenical. The first poison-spray application should be made as soon as the first beetles are found upon the vines. Our observations indicate that the beetles feed much more freely immediately after emergence from the soil

than they do several days later, during the period of egg deposition, and since the object of this application is to prevent egg deposition, it is very desirable that the poison application be made early, so that the first meal of the beetle will consist of poisoned foliage.

The beetles may be expected to appear on the foliage during the last week or ten days in June or the first few days in July, depending on the earliness of the season. After June 20 vineyardists should keep a sharp watch for their appearance and have their spray equipment in readiness to make the first spray application.

The development of the pupa in the soil will also indicate approximately the appearance of the beetles, for they may be expected to appear within a week or ten days after the pupæ can be found in the soil in considerable numbers. Since a large majority of the beetles emerge from the soil from ten to fifteen days after the appearance of the first beetles, it is necessary to make a second spray application within a week or ten days after the appearance of the first beetles. In this way it will be possible to keep the foliage well covered with poison spray during the emergence of a maximum number of the beetles.

Observations and experiments indicate that, if these two applications are made promptly and thoroughly, this pest can be reduced to such small numbers that it will not materially affect the vigor of the vines.

The spray formula recommended is as follows:

Arsenate of lead	pounds	3
Water	gallons	50
Copper sulphate (blue vitriol)	pounds	5
Lime (fresh lump lime)	do	5

The first ingredient of the formula, arsenate of lead, is the arsenical poison and the active killing agent or insecticide. The two last ingredients, copper sulphate and lime, with the water, form Bordeaux mixture, which is a fungicide used to control black rot, mildew, and other fungous diseases of the grape. Fortunately this insecticide and this fungicide can be mixed without changing the quality of either, and for this reason their use in combination is recommended.

DESTRUCTION OF THE PUPÆ.

In the vineyards throughout the Lake Erie grape belt pupation of the grape root-worm may be expected to commence about June 10, reaching the maximum about June 15 to 18. These dates can not be fixed, however, on account of variation in weather conditions. The exact time of pupation of the insect can best be determined by the person operating the infested vineyard by carefully removing the soil around the base of infested vines to a depth of from 2 to 4 inches.

When pupæ are discovered, the soil beneath the trellis should be removed by the horse hoe and the soil directly around the base of the vine carefully and thoroughly stirred with a hand hoe. The efficiency of this method of destroying the pupæ may be increased by throwing up a ridge of earth beneath the trellis during the last cultivation of the preceding summer. This will tend to encourage the insects to form their pupal cells above the roots of the vine and thus admit of their destruction by cultivation without serious injury to the roots of the vine by the horse hoe.

It is in these two stages—namely, the pupa and the beetle—that the insect appears to be most readily overcome; in fact, no effective measures have yet been developed for the destruction of the larvæ or of the eggs. Experiments conducted against the larvæ in the soil with oils, carbon bisulphid, fertilizers, salt, etc., have proved ineffective, and in some cases injurious to the grapevine; and since the eggs are deposited beneath the bark of the canes when the vines are in full foliage, it is practically impossible to reach them with a spray application.

GENERAL TREATMENT OF INFESTED VINEYARDS.

In addition to these recommendations dealing with direct means of controlling the insect in producing vineyards, a few suggestions are offered concerning the care and treatment of newly planted vines, and also of old, run-down vineyards in relation to this insect problem.

Serious injury is most likely to occur to young vines planted in soil on which infested vines were growing during the preceding season, for this soil is likely to be heavily infested with grape root-worm larvæ which will transform to beetles. These emerging beetles readily discover the newly planted vines and soon riddle the leaves of these small plants. For this reason it is very desirable, when the replanting of an old vineyard area is found necessary, that some annual crop be grown for at least one season, in order that the soil may be free of the insect when the new vines are planted.

In order that newly planted vines may be maintained in a thrifty condition during the period between planting and the bearing of the first crop of fruit, the vineyardist should keep a sharp watch during the month of July for the appearance of the grape root-worm beetles upon his young vines. When the beetles are numerous, they skeletonize many of the leaves, and this greatly retards the growth of the plant. If the infested vines are thoroughly sprayed with arsenate of lead at a strength of 3 pounds to 50 gallons of water, the injury by the beetles may be in a great measure prevented.

There is little danger that young vines will become reinfested during the first season, since there is a very limited amount of cane or stem upon which the beetle can deposit its eggs. By the second summer, however, the area upon which eggs may be deposited is somewhat increased, and we have discovered occasional egg clusters of this insect under the loose bark of the short stem of 1-year-planted vines and have also found a few larvæ at their roots late in summer, indicating that permanent infestation may take place early in the life of the vineyard. Hence it may be necessary to spray some vineyards from the time of planting.

Generally it is during the third season's growth of the vines, when the cane is trained to the trellis, that serious permanent infestation, by means of egg deposition by the beetle, takes place. The larvæ hatching from these eggs are especially injurious to these young vines, which possess but a limited root system compared with that of an old-established producing vine. It is the opinion of the writers that the first year or two of fruit production of young vines exposed to infestation is the most critical period of their existence, and especial care should be taken during that period to prevent infestation by the beetles. This can be accomplished by following the suggestions made on pages 89–90, giving directions for the destruction of the beetles.

When vines in a producing vineyard have been badly injured by this pest, such vines may frequently be renovated by cutting them back to the ground, so that the limited vitality of the injured vine may be devoted entirely to the making of vegetative growth. A heavy application of fertilizer should be made, consisting either of barnyard manure or a commercial fertilizer containing a high percentage of nitrogen. The vines should be thoroughly sprayed at the time the beetles make their appearance and thorough cultivation of the soil should be maintained throughout the season. The grapevine possesses remarkable recuperative power and, as the results tabulated in this paper, under the heading of field experiments, indicate, responds bounteously to careful and generous treatment.

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